The
ENGINEERS' DIGEST

REVIEW OF WORLD ENGINEERING PROGRESS

VOL. XX No. 2 FEBRUARY, 1959

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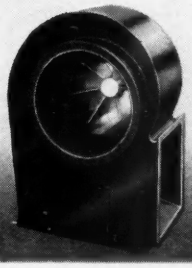

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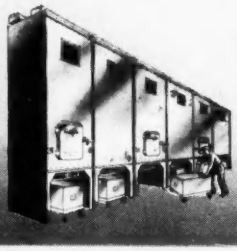

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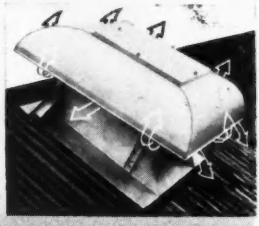

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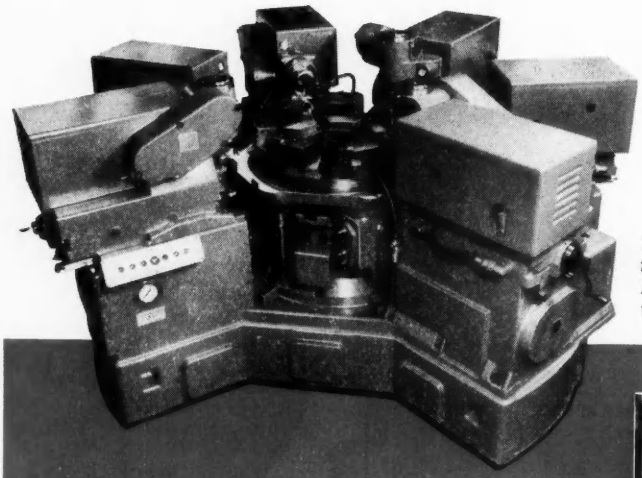
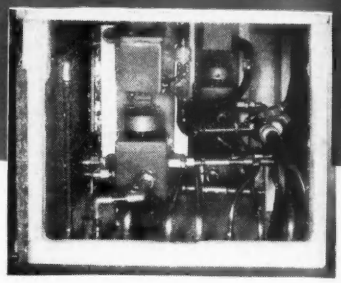


This 7-station rotary-transfer milling-machine made by High Precision Equipment Limited uses Keelavite hydraulics.



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THE BLUE PAGES

A QUICK GLANCE AT THE LATEST TECHNICAL DEVELOPMENTS THROUGHOUT THE WORLD

• *ELECTROLUMINESCENT TELEVISION SCREEN*

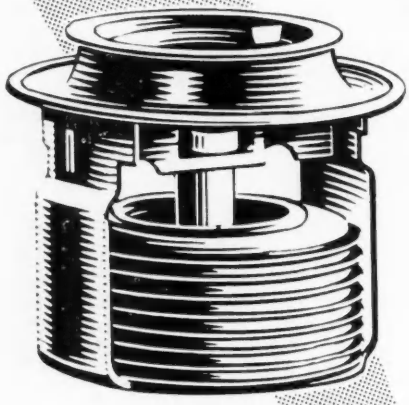
The cathode-ray tube used in most television sets suffers from the disadvantages of bulkiness and limited brightness and contrast. A new advanced type of television screen now under development is claimed to be brighter than any normal television picture tube, but is no thicker than an ordinary picture frame. It combines in a single thin structure an electroluminescent panel and a built-in storage and control system made of ferro-electric materials. In the conventional television picture tube, the picture is " painted " on the phosphor-coated inner surface of the tube by a beam of electrons which sweeps across the screen, creating new pictures at predetermined intervals of time. Ordinarily, the phosphors glow long enough after each time they are excited by the beam for the picture to look continuous. However, the fact that the phosphors are not continually excited reduces the average brightness of the phosphors and consequently the brightness of the screen. The new screen overcomes the problems of brightness and flicker by providing continuous excitation of the screen. Ferro-electric cells control the excitation of the screen in accordance with electrical signals in such a way that, once a certain picture is formed, the screen is excited to hold the picture until a different signal is received. The images can be stored on the screen for several minutes or can be changed many times a second. Because of the continual excitation, screens can attain a brightness three times that of the normal television tube and can produce contrast ratios of as high as 200:1. The most difficult problem of all, i.e., to find an alternative for the scanner beam, has not, however, been solved as yet.

• *CRYSTAL OSCILLATOR FOR MOTOR SPEED CONTROL*

An unusual application of a crystal oscillator is for the high-precision speed control of an electric drive for a 20-ft. diameter centrifuge used for subjecting extremely sensitive inertial-guidance components to a gravitational field. It is necessary to keep motor speed constant within 1 part in 400,000, the motor being an eight-pole three-phase synchronous machine. Adjustable-frequency power supply to the synchronous motor is derived from a three-phase electronic supply which controls the output of three rotary amplifiers, and which is infinitely adjustable in frequency from 0·33 to 7 cps, giving a motor speed range of 6 to 100 rpm. Voltage requirements are a function of frequency and vary from 5 V at minimum speed to 26 V at maximum speed, maximum output current being 200 A. The motor delivers 350 lb-ft torque at 100 rpm and accelerates synchronously from 6 to 100 rpm. The three-phase oscillator is based on an *RC* phase-shift network which is resistance-tuned by a three-gang 15-turn potentiometer. Maximum frequency stability is achieved by closely regulating plate, cathode, and filament voltages. Bias voltage is established by a mercury cell, and output amplitude is maintained by an automatic gain-control system which effects slight variations in plate voltage. Since the oscillator requires maximum temperature stability, the unit is enclosed in a heavy copper heat-sink with a mild-steel liner sunk below floor level in the chamber enclosing the machine. Final power amplification is accomplished by three rotary amplifiers, each of which consists of a single-phase commutated generator driven by a three-phase induction motor. The rotary-amplifier fields are controlled by the electronic power amplifiers.

• *HYPERSONIC GUN*

Research into the possible use of electric discharges for creating sudden gas pressures of high intensity and rapid propagation has led to the development of a hypersonic gun, operated by striking arcs between evenly spaced electrodes along a barrel, so as to heat a gas (preferably helium). The resulting expansion should force a projectile at increasing speeds down the barrel, producing a theoretically predicted muzzle velocity of 60,000 fps, i.e., vastly greater than that produced by a 16-in. cannon using conventional explosive propellants, with which a region of severely diminishing returns is reached if the muzzle velocity is pushed beyond the range of 5000 fps, although the theoretical maximum velocity obtainable with chemical propellants is somewhere below 25,000 fps. The principal factor responsible for this characteristic is the large mass of propellant that must be accelerated along with the projectile, causing a large pressure gradient to build up in the column of propellant gas behind the projectile. In order to reduce the mass of the propellant gas, it is therefore necessary to use some other gas than



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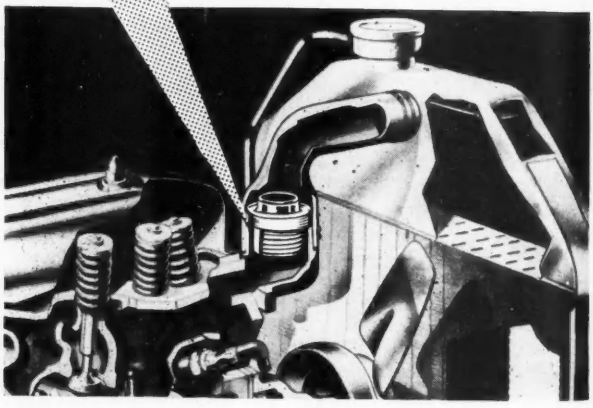

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conventional propellant gases, which have a molecular weight of from 20 to 25. This is the reason why helium, with its much lower molecular weight, is preferred. It is reported that the new arc-discharge gun has been devised for carrying out free-flight tests of models, possibly space vehicles.

• *ELECTRONIC MICROMETER*

An electronic micrometer has been devised for measuring the dimensions of small objects and more especially for facilitating the inspection of printed circuits. Measurements are taken by a multiplier-phototube control circuit which travels on a precision lathe, circuit output being fed to an electronic counter. The object to be measured is placed on a rotary index table, located directly beneath the lens system of a projector, casting a magnified image of the object which is reflected from a front-surface mirror onto the plane scanned by the multiplier-phototube, mounted with an amplifier and a mercury relay and counter on the cross-slide of the lathe. The slide travels down the ways of the lathe and, when the phototube reaches the image-area region, the relay is triggered and the counting cycle begins. The relay is de-energized at the end of the image zone, and counting stops. In the counter reading the image length multiplied by the magnification ratio is recorded. A counter-wheel with 125 holes, accurately indexed and drilled in its periphery, is geared directly to the main leadscrew of the lathe, each hole corresponding to 0·0001-in. slide travel down the lathe. The counter-wheel interrupts the light-beam-phototube-transducer system, which emits one output pulse per interruption as the slide propelled by the leadscrew travels down the lathe. The output pulse from the phototube is fed into the electronic counter, which registers the total number of pulses. The magnification ratio of object-to-image must be determined within the measuring accuracy of precision dial indicators. With a magnification of × 100, measurements to 1 micro-inch are theoretically possible but, allowing for shadow diffraction and measurement tolerances, measurements to 100 micro-inches are obtained in practice.

• *EXPLOSIVES FOR HIGH-VELOCITY METAL-FORMING*

Several reports have been published within the last few years describing the successes attained with the high-velocity forming of metals by means of detonating compounds. In one such process, a high-velocity explosive press is used, in which the forming head is carried by a ram attached to a piston, driven forward at great speed when a solid explosive charge is fired in the cylinder in which the piston moves. In another method, the explosive force of a solid charge is made to act directly on the metal piece to be deformed, while in yet another method the explosive is detonated in a confined liquid, which, in turn, exerts its mechanical effect on the part to be deformed. A considerable drawback attaching to operations of this kind is the danger inherent in handling such explosive charges as gunpowder or dynamite. It is therefore interesting to note proposals made in two recent patent applications which aim at eliminating this difficulty. According to the first proposal, the explosive is created *in situ* by relying on the electrolytic decomposition of a suitable electrolyte, such as water. The resulting hydrogen and oxygen are then electrically detonated when they have been produced in the required quantity. The second proposal envisages the use of an explosive charge which can be prepared immediately prior to use, and specific mention is made of the use of liquid oxygen. In this type of explosive charge, a mass of lamp-black is contained in a cartridge which, prior to use, is dipped into liquid oxygen. From the aspect of safety, these charges have the advantage that no magazine is necessary for storage, as is the case with other explosives. Also, should the prepared charge fail to explode, evaporation of the oxygen will render it harmless. A further advantage is that the mass of lamp-black can be given any suitable shape for the purpose intended.

• *HYDRAULIC-JET DESCALING*

Important advances have recently been made in the development of equipment for the hydraulic-jet descaling of material prior to forging, in order to obtain forgings free from embedded scale and scale pits. In preparing round bars for forging, a ring of spray nozzles was originally used, with water pressures up to 2000 psi. However, only some 60 to 80% of the scale could be removed, and a thorough analysis of the process has now been made. It is concluded that the sudden chilling of the crust of scale causes it to shrink and separate itself from the hot parent metal beneath. The scale is not loosened by the mechanical force of the water jet, but by the shrinkage of the scale, without a corresponding contraction of the parent metal. It is therefore considered advisable to strike the crust of scale with just enough water to chill it, but not enough to cool the parent metal materially. Further analysis has shown that, to use shrinkage to the best advantage, it is necessary for sudden chilling to hit the scale in a narrow band. To apply the water properly to round and square workpieces, a jet ring has been developed which produces a convergent cone of water aimed at the axis of the workpiece. This jet ring, comprising a single circular adjustable nozzle, is designed to produce an extremely narrow impingement band. With the workpiece passing through this jet,

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there is no time for the chill to penetrate the scale to the parent metal beneath, and full use of the scale shrinkage is therefore realized. For the descaling of flat pieces, another jet device, termed a "jet bar", has been developed in which the paths of the water droplets are not convergent, as they are in the jet ring, but are parallel. At a short distance from the jet bar, surface tension coalesces the droplets into a solid sheet of high-pressure water.

● *HIGH-FREQUENCY CRACK DETECTOR*

A recently patented method of detecting surface cracks in metallic bodies utilizes the fact that, if high-frequency oscillations are applied to an electrically conductive body, the resulting high-frequency currents are confined to the surface of the body, owing to the high-frequency skin effect. The presence of a surface crack will provide a discontinuity to the flow of current in the surface, and it is this effect which is used to detect the presence of cracks. Essentially, the device detects the change in the radio-frequency potential occurring between a pair of spaced search electrodes moved over the surface of a body supplied with radio-frequency oscillations, i.e., oscillations in the range between 400 kcs and 14·5 Mcs. The electrodes, which may be in the form of metal probes with pointed ends, are connected to the input circuit of an electronic amplifier, the output circuit of which delivers a suitable signal indicating the presence of a crack. Inspection is carried out by moving the search electrodes over the surface of the body, a substantially constant difference in radio-frequency potential being maintained between them as long as the conductivity of the body remains uniform. However, when a surface crack is present and the electrodes straddle it, the different resistance of the surface between the electrodes results in a difference in potential between the electrodes, so that the amplifier output changes and a corresponding signal is delivered to the indicating instrument. The radio-frequency oscillations can be supplied to the body by another pair of spaced electrodes brought into contact with the body to be examined. This type of crack detector provides a rapid, simple, and sharply definitive method of indicating surface cracks in conductive bodies and is said to be particularly suitable for detecting cracks in turbine blades.

● *ELECTROSTATIC GENERATOR AND IGNITION SYSTEM*

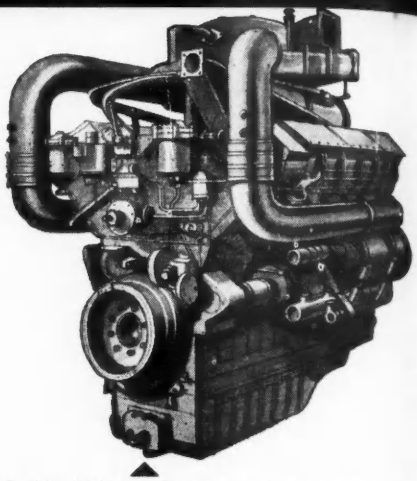
A new high-voltage electrostatic generator and ignition system utilizes the discovery that it is possible to convert mechanical energy into a very high voltage pulse with only a very low available voltage and without the use of switching contacts. The system is based on the principle that, after a condenser has been charged and if the plates are separated quickly, i.e., if they are snapped apart, the reduced capacity will be accompanied by an increased potential between the plates, and that in the particular circuit employed the potential is proportional to the rate or speed at which the plates are moved apart. The invention is claimed to be particularly useful in ignition systems, because a high ignition voltage can be produced by the condenser with only a relatively low voltage source. Furthermore, with internal combustion engines, the engine itself is available as the source of the mechanical energy required for moving the condenser plates towards and away from each other. Another especially significant feature is that it adapts itself to and makes possible the use of a radioactive battery as a source of potential; with such a battery, very high ignition potentials can be obtained, the actual energy for ignition being supplied as mechanical energy which is converted into electrical energy, so that there is very little drain of energy from the battery. Radioactive batteries are now available which are ideally suited for this purpose. In the basic arrangement, the condenser is charged and discharged through the same circuit, charging being effected with a battery having a relatively low potential. The battery is in series with a spark gap, across which the spark is produced when the condenser plates are mechanically separated. The discharge takes place through the battery, after which the condenser is again charged by the battery.

● *CAVITATION METHOD OF DETERMINING ULTRASONIC WAVE DISTRIBUTION AND INTENSITY*

A recently patented method of determining the distribution and intensity of ultrasonic waves at different points in a liquid is based on the fact that longitudinal ultrasonic waves comprise successive compression and tension zones which travel through the liquid. Small bubbles are developed in the tension zone, and these collapse sharply and produce local shocks. Determination of the distribution of these bubbles indicates the distribution of wave energy, while determination of their frequency and size indicates the intensity of the wave energy. In the new test method, a foil is immersed in the liquid in a zone in which cavitation is taking place. The sudden collapse or implosion of the cavitation bubbles in contact with or adjacent to the foil will deform the foil, producing a pit or dimple on one side of the foil and a projection or bulge on the

For further information on developments reviewed in THE BLUE PAGES, readers are invited to write to the Editor.

MAYBACH POWER MADE IN BRITAIN



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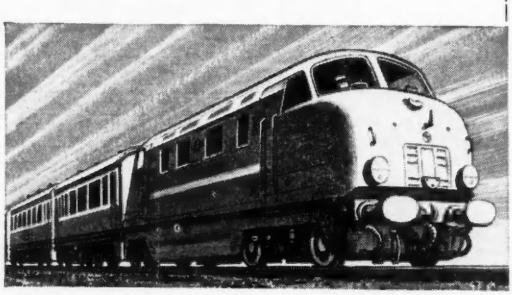

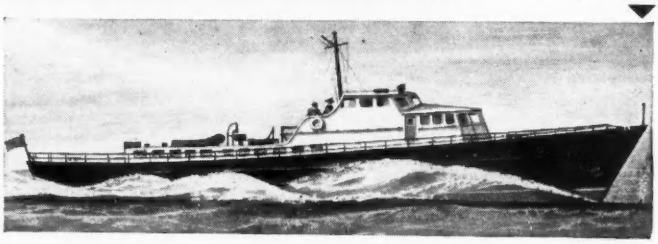

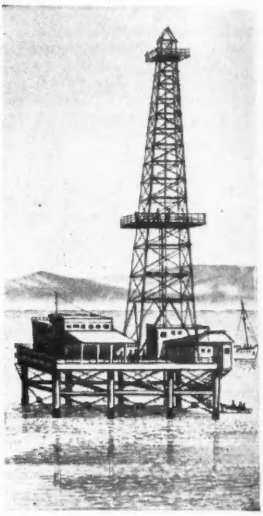

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opposite side. These dimples and bulges correspond in area and in height to the size of the bubble. The type and thickness of the metal foil suitable for testing will depend in particular on the energy which corresponds to the size of the cavitation bubbles in individual cases. If the sheet is too readily deformed or is too thin for a particular cavitation condition, it is liable to be ruptured, making it difficult to interpret the cavitation action. On the other hand, if the foil is too stiff or is too thick, some or all of the bubbles will fail to produce deformations and therefore will not register on the sheet. Lead foil has been found especially effective for testing ordinary cavitation conditions, since it is readily deformable, and deformations are permanently retained. Its thickness has to be chosen to suit particular conditions; for standard use it has been found that lead foil of 0·001 in. thickness is suitable for registering a wide range of cavitation energies without material rupture. Other suitable materials include tinfoil, about 0·003 in. thick, and aluminium foil, about 0·001 in. thick.

● *CONTINUOUS BILLET EXTRUSION*

The extrusion of metal from billets has hitherto been confined to processes which, owing to the type of equipment used, cannot inherently produce continuous extrusion. Thus, mechanical and hydraulic ram types of presses are generally used, and these employ the direct, inverted, or impact method of extrusion. It is obvious that these machines cannot provide really continuous extrusion, since the ram must be withdrawn after each stroke to place a new billet in the compression chamber of the machine. In order to overcome this shortcoming, a ramless metal-extruding machine, through which metal billets may be extruded in a continual stream, is proposed. In this machine, one billet after the other is forced by a roller-type conveyor into an extrusion cylinder, which carries the die-plate at its front end, both the cylinder and die-plate being heated by separate induction coils. These coils are separated from the cylinder and die-plate by electrically and thermally insulating sleeves. In operation, after the cylinder and the die-plate have reached appropriate temperatures, the first billet is pushed by the power rollers into the cylinder and is pressed against the die-plate, receiving heat by conduction, as well as eddy-current heating. The heat and pressure acting on the leading end of the billet plasticizes the end sufficiently for extrusion to take place. Once extrusion has commenced, a column of billets is then forced through the cylinder in a continuous stream. It is stated that, although the machine has basically been designed for extruding billets of aluminium or aluminium alloys, it can also be applied to billets of tin, copper, magnesium, zinc, and their respective alloys. When induction heating is used for non-magnetic materials, the cylinder and die-plate should be constructed of a suitable material (e.g., a steel alloy containing 25% nickel) to ensure that the magnetic lines of force pass through the billet and that the eddy currents in the cylinder and die-plate are not excessive; otherwise, the billets may not be heated solely by conduction from the cylinder and die-plate.

● *ELECTRIC INDUCTION LAMP*

Incandescent filament lamps used for projection devices, film printers, and similar devices have a series of parallel filaments arranged side by side in a plane. In an optical system, the image produced by such a series of filaments is obviously non-uniform in brightness and, in order to reduce the non-uniformity, the system has to be defocused by focusing the image at a point other than that at which the light is to be used. For example, in a film printer, the so-called " film-gate " is the position at which the light is desired, but the image of the filament is focused at a position beyond the gate, so that the image is sufficiently out of focus at the gate to blur it and give a more uniform light pattern. Such defocusing, however, entails a considerable loss of light, which, for reasonable uniformity, can be as much as 73% in a conventional projector system, leaving only 27% available at the film-gate. Uniform brightness can be achieved by using as the light source an inductively heated refractory body or " target ", and a recent patent proposes to use a target of such a material as hafnium carbide, tantalum carbide, or niobium carbide, heated inductively by a coil located around it and carrying a high-frequency current. A field concentrator between the coil and the target is used to improve efficiency, and is in the form of a metal cylinder having a slot so as to prevent the circulation of current in it. In order to improve uniformity of brightness, the target is made thinner on the side near the slot, so that the heating effect at this point is increased. It is stated that an induction lamp of this type has a symmetrical non-uniformity of less than 10% and an asymmetrical non-uniformity of less than 5%, making it suitable for even the most critical applications.

"THE MINIDIGEST"

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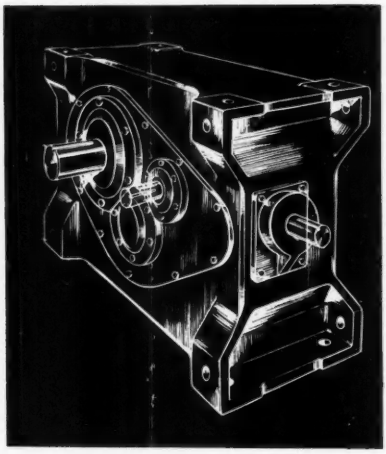

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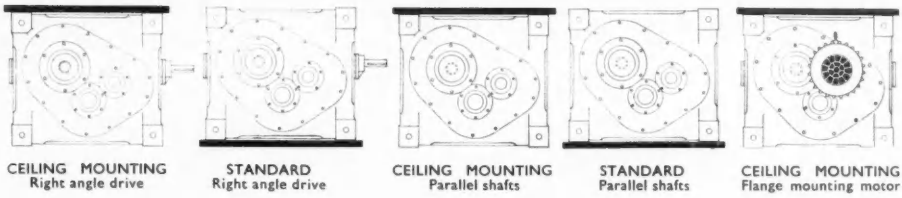
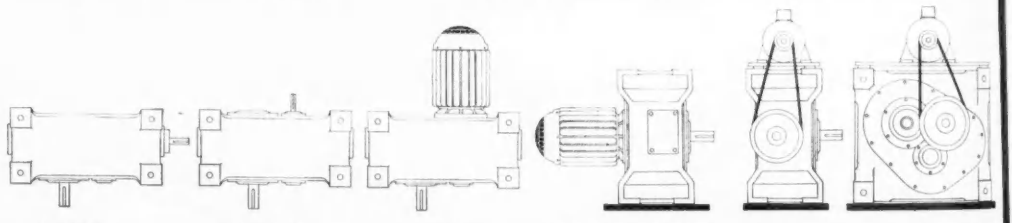


CEILING MOUNTING Right angle drive | STANDARD Right angle drive | CEILING MOUNTING Parallel shafts | STANDARD Parallel shafts | CEILING MOUNTING Flange mounting motor



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THE ENGINEERS' DIGEST
REVIEW OF WORLD ENGINEERING PROGRESS
VOL. XX No. 2 FEBRUARY, 1959

The Mechanism of Electrolytic Rectification

By P. WINKEL and B. VERKERK. (From *Philips Technical Reports, Holland*, Vol. 13, No. 6, December 1958, pp. 502–505, 2 illustrations)

It is well known that, after the anodic oxidation of such metals as tantalum and aluminium, the system comprising metal, metal oxide, and electrolyte shows rectification. However, the origin and seat of this property are unknown, and whether this rectification is uniform across the surface or whether it is restricted to many spots on the surface is still an open question. This paper, which deals with aluminium oxide layers only, shows that, up to now, there are no definite indications of " point " rectification.

If a sheet of aluminium is etched for 3 min in hot 5% NaOH and subsequently for 1 min in cold 20% H_2SO_4, examination of a replica of the surface under the electron microscope shows that the surface contains a series of " plateaux " of about 0·1μ in diameter, often found together in groups. Moreover, impure aluminium (99·5%) shows many more of these spots than pure aluminium (99·99%), in which only a few spots can be noted. As a result, these plateaux can be ascribed to segregations in the aluminium of impurities which are subjected to less attack by the alkaline and acid treatment than the aluminium atoms.

Similarly, if a sheet of aluminium, treated as described above, is oxidized anodically and the oxide layer is separated from the aluminium by a methanol-bromium treatment, examination of this layer under the electron microscope reveals a number of holes, which in some respects show a strong analogy with the plateaux mentioned above. This confirms expectations, i.e., that on the locations of the impurities no oxide, or only some oxide, will grow.

Experiments have been made in connection with aluminium sheets which, after oxidation, were placed in a radioactive gold solution. After a short time, e.g., 30 sec, some activity was observed on the sheets. As it is not possible for the gold ions to exchange with the aluminium ions of the oxide in the case of no external voltage, it has been suggested that there are " open " areas in the oxide, caused by impurities on which the gold can be deposited by electrochemical displacement. It is true that, in this case, the active spots are much larger than those in the two cases previously mentioned, but, taking into account the existence of groups of small spots and the limited resolution of the autoradiographs obtained, it may be said that essentially there is no contradiction in the results of these experiments. In fact, calculations of the observed activity show that quantitatively the larger spots may consist of a number of small spots.

It may be stated that, during the growth of the oxide layer, weak places or even holes (which should not be confused with the equally spaced pores present in oxide layers formed in oxalic or sulphuric acid baths) remain when impurities are present in the underlying base metal.

If rectification were to take place at isolated points and not uniformly across the oxide layer, it could be assumed that these points could be correlated with the open spots referred to above. This assumption has two consequences, one of which is that the current level in both forward and blocking directions will naturally be higher with impure aluminium than with pure aluminium (with a different number of spots). At the same time, however, the rectification factor, i.e., the ratio of the two currents, will be independent of the purity of the aluminium. It is difficult to determine this factor experimentally.

The second consequence of this assumption is that, if contact of the electrolyte causes rectification, it is likely that this would also be observed in the case of a capillary filled with electrolyte in contact with a sheet of copper, iron, or platinum. However, rectification is not observed in this instance. Consequently, these results do not show any evidence substantiating point-contact rectification.

In a recent article*, it was pointed out that, during the forward current, the hydrogen bubbles at the oxide/electrolyte interface originate from quite definite spots on the surface and not at random. After the voltage has been reversed for some time, the bubbles again originate from the same spots. However, some new places are also created, and some old places stop bubbling. Now, these located " craters " need not be an indication that the current flows through these places only. Thus, it is well known that, on a platinum electrode, bubbles evolve from well-defined places, whereas the discharge is uniform; also, when these places are masked, new spots come into existence. Although the spots of the impurities will certainly be favoured points for these " active " places, this is no proof that the discharge would not be uniform.

It might be thought that, by scanning the surface with a very thin metal wire, the spots of rectification should be located; it is well-known, however, that, by replacing the electrolyte with a metal (e.g., by evaporating this metal onto the oxide), there is often no rectification left. Although the background of this fact is not quite clear, this makes the suggested method doubtful. In fact, with scanning no rectification was observed though this does not seem in contradiction with a uniform rectification in the case of the electrolyte electrode.

CONCLUSIONS

There is no coercive evidence of a rectification mechanism being present only at small spots on the surface. However, the spots certainly will contribute to secondary effects, especially to the " leakage " current. On the other hand, some emphasis should be laid on the following facts:—

(*a*) The property of rectification is independent of the treatment of the aluminium surface and is also independent of the impurities.

* D. A. VERMILYEA: *Jour. Applied Physics*, Vol. 27, 1956, pp. 963-964.

(*b*) Rectification is macroscopically the same for quite different materials. Thus, tantalum also shows electrolytic rectification (after anodic oxidation) when quite different impurities are present, arranged in quite different ways and eliminated differently by different surface treatments. In addition, the large absorptivity of tantalum for hydrogen atoms will create a situation at the tantalum electrode which is completely different from that of aluminium.

Finally, it may be said that electrolytic rectification can still be considered as a uniform process, although this process itself may not be known exactly.

U.S.A.

A Brushless D.C. Generator for Aircraft

By J. T. Duane. (From *Applications and Industry* (*A.I.E.E.*), No. 39, November 1958, pp. 365–372, 13 illustrations)

The commutator has long been a distinctive and sometimes troublesome feature of d.c. generators but, although a d.c. generator can often be replaced by an a.c. generator with its output completely converted to direct current by static rectifiers, economics and application requirements have seldom justified the increased complexity and cost.

In modern aircraft applications, the increasingly severe environmental requirements placed on generating equipment have made it more and more difficult to obtain the necessary reliability and service life from commutator and brush systems. Higher altitudes have necessitated continual improvements in the ability of such commutator systems to work under low-humidity, high-temperature conditions. In addition, demands for lighter-weight generators have resulted in electrical designs which make satisfactory commutation even more difficult to obtain. The logical result of these trends is the elimination of mechanical commutators in certain airborne d.c. generating systems. The development of such a system, intended for use in a modern high-performance fighter aircraft, is described in this paper.

The system, rated at 100 A, 30 V d.c., requires no brushes and, in addition, eliminates the need for a carbon-pile type of regulator. Since the machine is designed for a high-performance aircraft, it is required to function in an exceedingly high-temperature environment, and generator cooling is accomplished by the circulation of oil, rather than by the use of blast air.

Generating System

The combination of components used to obtain brushless d.c. generation is shown in Fig. 1, in which it will be noted that the various elements are combined in two separate packages. Thus, the exciter, the main output generator, and the rectifiers are included in the generator itself, with provision for cooling by oil circulation, while voltage regulation and protective functions are incorporated in a separate control panel which requires no forced cooling.

Examination of Fig. 1 shows that an unusual approach has been adopted for the supply of excitation power to the main generator. Most d.c. machines are self-excited by feeding back the d.c. output to the field winding through a variable resistance which, in most aircraft systems, is a carbon-pile device sensitive to vibrations and to the accelerations imposed by manoeuvring and shock loads, with the consequent risk of instability. For this development, excitation power is supplied through a magnetic-amplifier type of regulator by a 1600-cps permanent-magnet generator mounted on the main generator shaft, eliminating the need for a carbon-pile regulator. The magnetic-amplifier regulator can be utilized to convert the 1600-cps output to direct current for excitation purposes, and to provide control power at the same time.

Other advantages of this alternative arrangement are that the use of permanent-magnet excitation eliminates the need for the field flashing circuits often provided to ensure generator build-up, and that the high-frequency permanent-magnet generator, in conjunction with the magnetic-amplifier regulator, permits an exceptionally fast system response, compared with more typical d.c. systems. Furthermore, the availability of a separate excitation source, independent of generator line voltage, makes it possible to supply high short-circuit currents without battery assistance. In other words, the system will not collapse like a typical d.c. system under a short-circuit, thereby improving the ability to clear system faults.

The main output generator is a double-ended, homopolar inductor alternator, its 12-pole construction providing an 800-cps output frequency at the rated speed of 8000 rpm. The design of this inductor eliminates not only brushes and commutator, but also all rotating windings, resulting in a rugged and highly reliable construction and minimizing maintenance problems. An added advantage is that it requires low levels of excitation power, thus simplifying the excitation and control system.

The oil circulation system for the application supplies oil separately to the generator rotor and stator, thus eliminating the need for any high-pressure rotating oil seals. Oil enters the stator through the face of the mounting flange and is circulated first to the rectifiers and then returned by a path which takes it around the outboard bearing and through tubing on a series of passes around the stator frame to provide cooling at this location. From this point it is returned to the constant-speed-drive gearbox. It is then supplied directly to a tube in the centre of the rotor shaft, which carries it down the length of the shaft to cool the inner race of the outboard bearing. In returning along the inside of the outer shaft, it provides the small amount of cooling necessary to remove stray pole-face losses from the rotor structure. A small amount of oil is bled from the shaft just before it leaves the machine, to provide lubrication for the drive-end bearing.

In operation, the entire generator is pressurized to 7 to 9 psig with purge air to prevent the flow of oil (particularly oil mist) from the constant-speed drive back into the generator. To minimize the leakage of this purge air from the generator cavity to the drive, a clearance-type labyrinth seal is provided, limiting air leakage in this area to 0·5 cfm with an 8-psi pressure differential.

The a.c. regulator uses a Zener diode type of reference and a transistor pre-amplifier, providing a transistorized and static voltage regulator which is not subject to the acceleration and vibration sensitivity problems sometimes associated with d.c. regulators. Circuitry in the regulator compares generator output voltage with the Zener diode reference, and the resulting error signal is

mplified in the transistor circuit. Transistor output establishes the current in the magnetic-amplifier control winding, which in turn controls the amount of power from the permanent-magnet generator fed through to the main generator field winding, so as to maintain generator voltage constant.

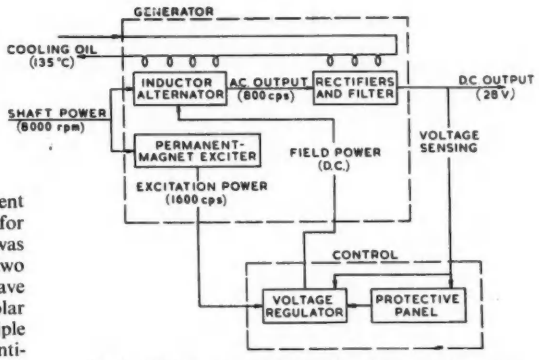

Fig. 1. Block diagram of the brushless d.c. generating system.

Inductor Alternator

In the development of this system, many different types of generator could have been applied, but, for various reasons, the use of an inductor alternator was considered the most suitable. There were, however, two different types of inductor alternator which could have been used, i.e., the heteropolar type or the homopolar type. The heteropolar inductor alternator uses multiple d.c. field poles created by field windings lying in essentially the same axially-directed slots as the a.c. output winding. In the homopolar type of machine, one coaxial field coil provides all the excitation, with no sacrifice of slot space in the stator. The homopolar approach proved the more effective since it permitted a lower-weight generator for a given output. In addition, it made it simpler to provide a complete balance between the various phases of the a.c. output. Phase balance can be achieved in the heteropolar device, but in some cases this requires a certain amount of sacrifice in weight.

In the homopolar inductor alternator, the north poles are all placed at one end and the south poles at the other, as shown in Fig. 2. All the magnetic flux passing from the south poles to the north poles internal to the rotor must go through the centre portion of the shaft, and a single, coaxial field coil around the shaft at this point will link all the flux and supply all the necessary excitation. This coil does not have to rotate and can therefore be fixed in the stator, eliminating the need for brushes or other sliding contacts.

It is evident from Fig. 2 that the flux must travel axially both in the centre of the rotor and outside the stator core. To accommodate this flux, solid-steel paths are provided at both points. The coaxial coil is required to supply only as many ampere-turns as originally supplied by two of the separate coils of a conventional salient-pole synchronous generator, in which the alternatively north and south poles of the rotor are induced by d.c. field windings around each pole-piece.

In the actual rotor developed for this application, stagger is provided in the rotor poles, in order to minimize slot ripple effects which would otherwise be reflected as ripple in the d.c. output. The rotor teeth at the two ends are offset from each other by one-half pole pitch to obtain the 180-deg. phase reversal necessary in the homopolar type of machine, since flux crosses the gap from rotor to stator at one end and from stator to rotor at the other.

One choice usually unavailable in design problems is the selection of frequency for the main output generator. In most a.c. designs, output frequency is fixed by system requirements. In this case, since the output is to be converted to direct current, there were no such restrictions. Consideration of all the factors involved led to the design of the inductor for this application as a 12-pole unit providing 800 cps at its operating speed of 8000 rpm.

Design of the generator to obtain the proper reactances for optimum system weight and performance presented other problems. One factor not usually available to the designer as a variable was the choice of the number of phases, depending largely on the characteristics of the rectifying system. The final design resulted in a relatively low reactance. The synchronous reactance of the a.c. machine was considerably lower than that of most typical aircraft alternators. On an equivalent per-unit basis, it was about 0·5, as compared with 1·2 to 2 for typical a.c. machines.

The electrical characteristics of the complete generator (with rectification) are not significantly different from those of a conventional d.c. machine. One peculiar characteristic of inductor machines is that, as field current is increased, the slope of the saturation curve passes through zero and becomes negative. In other words, terminal voltage starts to decrease with increasing field current above a certain point. Although this occurs in the present generator, the critical field-current point is well above the ceiling-power capabilities of the excitation system.

Rectification

Development of the rectifying system for this application presented several interesting problems, the major limitation being in the variety of available silicon rectifiers capable of operating at the required temperatures. An additional limitation was imposed by the fact that the cooling medium was at times only 50°C lower in temperature than the maximum junction temperature at which most of the rectifiers could be operated.

There are many rectifier combinations which might have been used in conjunction with various alternator-

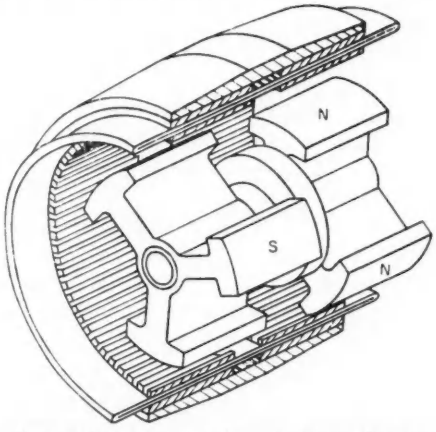

Fig. 2. Basic arrangement of a homopolar inductor alternator.

winding arrangements. However, after analysing the advantages and disadvantages of a number of possible rectifier connections, including a six-phase star configuration, a three-phase double-Y arrangement with interphase transformer, and a five-phase full-wave bridge configuration, the rectifier connection finally chosen was the three-phase double-way arrangement shown in Fig. 3. This circuit does not require any more rectifiers than the others, but the individual cells must have a higher current rating. It minimizes generator size, since it causes the lowest winding losses and demagnetizing effects of any other three- (or six-) phase schemes. In addition, the double-way connection provides minimum peak inverse voltage on the rectifiers, though it doubles the forward voltage drop which the generator detects in the rectifier.

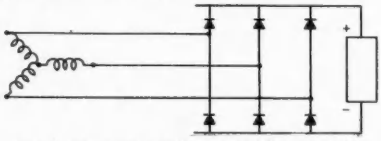

Fig. 3. Three-phase double-way rectifier connections.

Cooling of the rectifier assembly is accomplished by removing heat from a large stud at the bottom of the individual rectifier cells. The rectifier junction is limited to operating temperatures of approximately 200°C, and the thermal configuration of the stud and junction is such that a temperature rise of approximately 0·8°C for every watt dissipated is necessary between the stud and the junction. Since these rectifiers have losses of approximately 35 W each at full load, the generator must be installed and cooled in such a way that the stud temperature is maintained at a maximum of 172° C. Actual operating stud temperatures are somewhat lower, to allow for transient overcurrent conditions. A further complication is introduced because requirements for integrity of the oil system prevent direct contact between cooling oil and rectifier stud. This cooling problem was solved by the use of rectifier cooling plates, two plates providing paths for both current and heat flow from the rectifiers. Oil is circulated within the plates around the base of each of the individual rectifiers to provide maximum cooling. This configuration proved extremely effective, with a maximum temperature differential between inlet oil and the top of the rectifier stud of approximately 15°C under rated cooling and load conditions. Oil flow between the rectifier plates and the generator endshield is accomplished by means of holes in the face of the plates, encircled by O-rings for providing the necessary hydraulic seal. Thus, electrical isolation of the plates is possible. In actual practice, only one of the rectifier plates is isolated from its mounting surface. The negative side of the generator output is directly grounded internal to the generator. The second plate, corresponding to the positive terminal of the generator, is, of course, isolated. Electrical insulation between the two plates is provided by a sheet of Teflon, which establishes the necessary barrier to current flow but does not in itself perform any sealing function. The Teflon provides an interface, against which O-rings in each of the two adjacent plates are pressed to make the necessary oil seals. The Teflon gasket serves a second function as a supporting structure for leads associated with the filter assembly.

The effectiveness of the rectifier-cooling provisions are illustrated by the rating curves in Fig. 4, in which minimum allowable cooling-oil flow through the generator is shown as a function of oil inlet temperature. Rectifier temperatures place the major restriction on rating, since specification restrictions on efficiency precluded a generator design with losses high enough to make the windings thermally limiting.

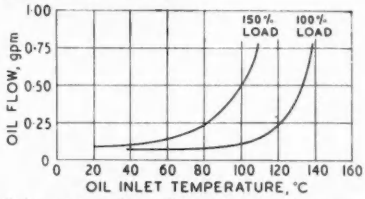

Fig. 4. Minimum permissible cooling-oil flow through the generator as a function of oil inlet temperature.

In the development of this generator, many different approaches were considered and evaluated for the reduction of the audio-frequency ripple in the d.c. output voltage. Considerable work was done on the reduction of ripple by shaping of the generator output wave-form. Fig. 5a shows one generator output wave-form used in the study of some of the phenomena associated with rectifier commutation. The step in the trailing edge of the voltage wave was designed to provide a fixed commutating voltage for the rectifiers when operating in a 6-phase star connection. However, although this approach to output wave-shaping proved effective and, in fact, permitted positive control of the magnitude of ripple, it was not adopted, because it would have required an excessively low reactance (i.e., a very large generator) to make it effective at the current levels required for this application. The wave-form in Fig. 5b was selected because it permitted maximum generator output.

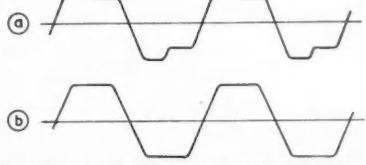

Fig. 5. Generator output wave-forms under no-load conditions, showing (a) a trial wave-form for optimum commutating voltage, and (b) the wave-form used in the final design.

Most rectifier applications use large inductors or chokes in the d.c. line to provide a high reactance or impedance to ripple currents, so that the ripple voltage appears entirely across the inductor. While several different inductor configurations were considered and evaluated for this application, they did not prove suitable, because of the weight required. The problem was further complicated by the fact that, since the inductor had to carry full d.c. load current, it was difficult to cool properly. A much more effective and economical solution from a weight standpoint was the inclusion of capacitors to provide a low impedance shunt path for the high-frequency (4800-cps) ripple, so that only a small portion of it appeared across the load. The final configuration uses 240 microfarads of capacitance directly across the d.c. output. This type of filter was made possible by recent developments in small, high-temperature tantalum capacitors. The 240 microfarads of filtering is obtained from three 80-microfarad capacitors rated to operate at temperatures up to 200°C. The highest temperature actually required of these capacitors in 155°C. The capacitors are mounted directly on the bottom of the rectifier plate, to make a complete assembly.

Improved Design of Fan with Drum-Type Rotor

By H. Laakso. (From *VDI Zeitschrift*, Vol. 101, No. 2, January 11, 1959, pp. 41-44, 6 illustrations)

Despite their high flow losses, fans utilizing drum-type rotors with bent-forward blades are often used because of their low cost, low peripheral velocities, and low noise level. Recently, considerable effort has been concentrated on reducing these flow losses, which account for about 50% of the power required.[1] In this connection, however, difficulties are only to be expected, as the load on the casing is much greater than it is with conventional high-performance centrifugal fans. A fan with a drum-type rotor will therefore still have a lower efficiency, even if the rotor is made as efficient as that of a high-performance fan. This is obvious when it is realized that, for the same rotor diameter and overall pressure rise, the drum-type rotor copes with a mass flow which is 2·5 times as high as that of a high-performance fan; consequently, its casing loss becomes about 6 times as high, and this factor alone reduces its efficiency from the theoretical optimum of about 90% to about 75%.[2] These considerations indicate that the losses cannot be reduced to less than 25%.

Flow machines have been, and still are, classified according to their specific speed. In such classifications long-bladed radial machines are included among the slow-speed types, while most axial machines are listed as high-speed types. More recent investigations, however, show that comparative assessments of flow machines require the use of several parameters, i.e., the head coefficient ψ, the capacity coefficient φ, the specific diameter δ, and the specific speed σ. These are defined as follows:—

$$\psi = \Delta p / \tfrac{1}{2}\rho u_2^2 \quad .. \quad .. \quad .. \quad (1)$$

$$\varphi = V / u_2 A_2 \quad .. \quad .. \quad .. \quad (2)$$

$$\delta = D \left[\frac{\pi^{\frac{1}{2}}}{2} \frac{(2gH)^{\frac{1}{4}}}{V^{\frac{1}{2}}} \right] = \frac{\psi^{\frac{1}{4}}}{\varphi^{\frac{1}{2}}} \quad .. \quad (3)$$

$$\sigma = n \left[2\pi^{\frac{1}{2}} \frac{V^{\frac{1}{2}}}{(2gH)^{\frac{3}{4}}} \right] = \frac{\varphi^{\frac{1}{2}}}{\psi^{\frac{3}{4}}} \quad .. \quad (4)$$

where Δp = total increase in pressure of the fan, ρ = gas density, u_2 = blade-tip velocity, V = flow rate, A_2 = surface swept by a rotor of diameter D, g = acceleration due to gravity, H = delivery head, and n = running speed.

A different classification has been put forward by Cordier,[3,4,5] who has plotted, for the various types of flow machines, the specific diameter δ against specific speed σ. On this basis, nearly all flow machines have their optimum points situated within a certain region bounded by curves of approximately hyperbolic shape, low δ-values corresponding to high σ-values, and high δ-values to low σ-values. Thus, it appears that a compact construction (i.e., of small diameter) is obtained at the cost of high running speed,[6] which is associated with increased noise at high frequencies. Also, high-speed fans tend to be more liable to give trouble and to have a shorter service life than slow-speed fans, which are quieter, although of larger size.

As indicated above, both δ and σ can be regarded as functions of the head coefficient ψ and the capacity coefficient φ. If minimum size is desired, a large φ-value is necessary, since eq. (3) shows that the capacity coefficient is then more important than the head coefficient.

If low noise level is the primary requirement, the blade-tip velocity u_2 of the rotor must be considered, since it is the main factor determining noise level [7,8]. For peripheral speed, and hence as a criterion of noise level, the corresponding non-dimensional parameter is obtained from eqs. (3) and (4) as

$$\sigma\delta = 1/\psi^{\frac{1}{4}} \quad .. \quad .. \quad (5)$$

Thus, to have a low noise level, a large head coefficient ψ should be used. Furthermore, it can be seen that, for low cost, low noise level, and economical operation, three requirements must be fulfilled as far as possible, i.e., (1) a large capacity coefficient φ, (2) a large head coefficient ψ, and (3) low flow losses.

Methods of Reducing Flow Losses

Some drum-type rotors have been built in the past which fulfil the first two conditions listed above, with φ-values of 0·5 to 0·7 and ψ-values from 1·5 to 2·5, associated with small dimensions and low noise. However, owing to their flow losses, these machines have efficiencies of about 55%, making them uneconomical.

Despite the above considerations, the results of tests on which this report is based show that it is possible to reduce the flow losses of such drum-type rotors in two main ways, i.e.,

(1) by means of a special inlet nozzle creating a considerably divergent flow to the rotor, which thus must have a section of appreciable width on its inlet side; this arrangement reduces inlet velocities and inlet losses; and

(2) by increasing the forward curvature of the simple sheet-metal blades of the rotor (up to an exit angle of 180 deg. or more); the angle covered by the blades is then greater than 90 deg., as distinct from previous practice[9]. In this way, an acceleration is maintained in the blade passages, preventing flow separation. In addition, this extreme curvature of the blades allows high head coefficients to be obtained.

With an exit angle of 180 deg., the peripheral component of the exit velocity becomes theoretically infinitely great, so that Euler's equation used for turbines is no longer applicable in calculating total pressure. The development of this drum-type rotor has therefore mainly been based on tests.

Experimental Investigations

Initial tests to determine the arrangement with the smallest possible flow losses were carried out on a prototype fan with a rotor diameter of 35 cm; at a later stage acceptance tests were made on a mass-produced fan with a rotor of 63 cm diameter.

In the arrangement used for these tests, air is admitted into the flared end of a trumpet-shaped inlet section through a flow-rectifying grille, and, after passing through a straight cylindrical measuring section, reaches a measuring orifice, ahead of which are fitted a thermometer and an aspirating psychrometer. The air then flows through another straight section, provided with a precision manometer for measurements of effective pressure, a static-pressure measuring unit, and a microphone connected to a noise-meter, finally entering the fan casing.

Accurate measurements[10] were made of head coefficient ψ, of capacity coefficient φ, of overall efficiency η, and of power coefficient λ. The power coefficient λ can be

defined by the following relations:—

$$\lambda = \varphi\psi/\eta = L/\tfrac{1}{2}\rho A_2 u_2^3 \quad .. \quad (6)$$

where L = required shaft power. The results are shown in Fig. 1. If the choice of a fan is to be based on an overall efficiency η of 70%, the range to be considered is from $\varphi = 0{\cdot}6$ to $1{\cdot}1$. The maximum head coefficient $\psi = 3{\cdot}0$ is obtained for $\varphi = 1{\cdot}0$.

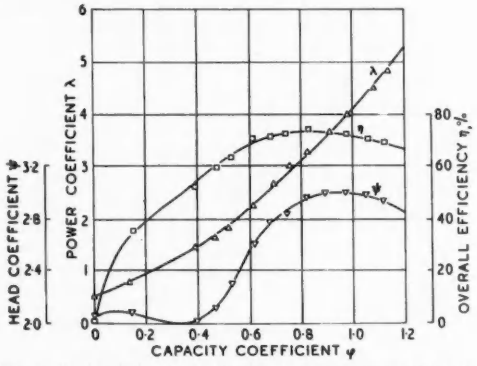

Fig. 1. Head coefficient ψ, overall efficiency η, and power coefficient λ as functions of capacity coefficient φ for the test fan with drum-type rotor.

The φ-values below unity have certain advantages[11], owing to the steeply decreasing ψ-values in this region, and these advantages can be seen by comparison with those for a high-performance fan, as shown in Fig. 2, which gives comparative values, in terms of V/V_o (volumetric flow ratio) as a function of $\Delta p/\Delta p_o$ (pressure-increase ratio), referred to a basic point A with values of unity.

When the resistance parabola (curve *a*) is determined and it is required to pump a constant volume into the system, the $\Delta p/\Delta p_o$ curve of the fan is unimportant, since both types of fan have a value of 1·0 at the basic point A. However, as soon as the volume is throttled down temporarily to smaller values, e.g., to a new point B at $\varphi = 0{\cdot}5$, the conditions become different. For $V/V_o < 1$, the back-pressure of the fan with a drum-type rotor is lower than that of the high-performance fan, which then has to produce additional work equal to the shaded area in Fig. 2. Consequently, a simple throttle control of such fans is always uneconomical. Admittedly, special regulating devices (such as throttles operating with adjustable inlet vane control[12]) have been developed, and these permit economical regulation, though they are used only in rare cases, owing to their cost. This is particularly true in the case of ventilation plant, which has a low resistance, even at high air flows. For such plant, the fan with a drum-type rotor designed in accordance with the above principles is particularly suitable.

Another comparison of the two fans, showing overall efficiency η and

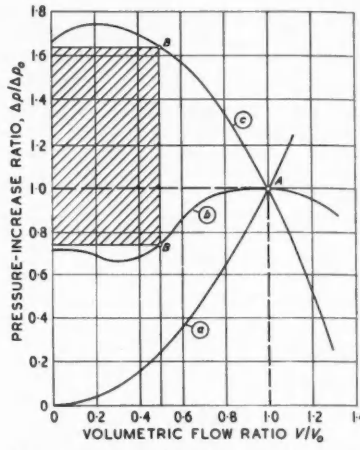

Fig. 2. Comparative characteristics of a high-performance fan and the test fan with drum-type rotor.
(a) Resistance parabola of the system.
(b) Characteristic of the test fan with drum-type rotor.
(c) Characteristic of the high-performance fan.

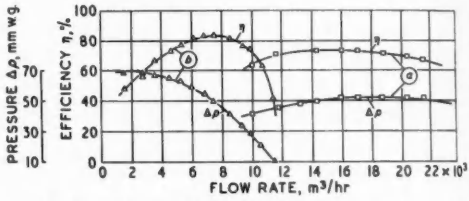

Fig. 3. Comparative overall efficiency η and total pressure increase Δp as functions of flow rate V for (*a*) the test fan with drum-type rotor, operating at 515 rpm, and (*b*) a high-performance fan, operating at 1080 rpm.

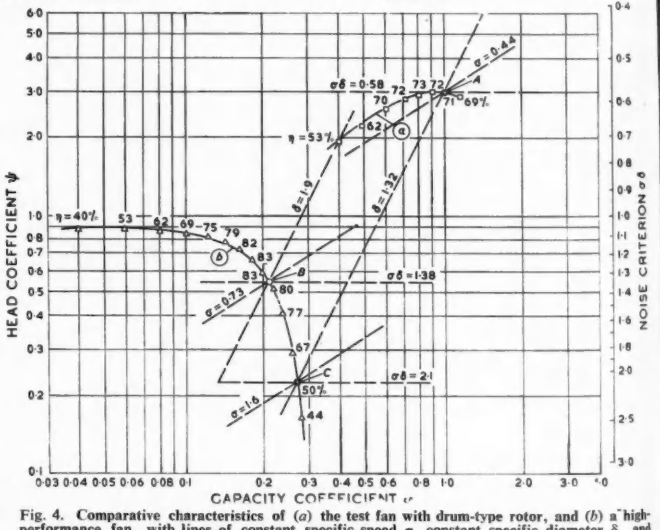

Fig. 4. Comparative characteristics of (*a*) the test fan with drum-type rotor, and (*b*) a high-performance fan, with lines of constant specific speed σ, constant specific diameter δ, and constant noise criterion $\sigma\delta$.
A = operating point of the test fan.
B = operating point of the high-performance fan.
C = operating point of the high-performance fan for the same value of δ as at the operating point A.

total pressure increase Δp as a function of flow rate V is given in Fig. 3. In this instance, the two fans had rotors of equal diameter and identical volute casings. The remarkable point is that the drum-type fan delivered 2·4 times the flow volume at the same pressure and at approximately half the running speed. This explains the reduction in efficiency from 83% to 70% between the two types of fan, since the casing losses of the drum-type fan are about six times as great as those of the high-performance fan.

TABLE I: CHARACTERISTIC PARAMETERS OF A HIGH-PERFORMANCE FAN AND A FAN WITH A DRUM-TYPE ROTOR

Fan Type	ψ	φ	δ	σ	$\sigma\delta$	η
High-performance	0·54	0·21	1·90	0·73	1·38	0·81
Drum-type rotor	3·00	1·00	1·32	0·44	0·58	0·71

With regard to fan size and noise-level, some results are given in Fig. 4, in which $\sigma\delta$ is the blade-tip velocity parameter or noise criterion[13]. Under otherwise similar conditions, the fan with a drum-type rotor has a 30% smaller diameter and a 58% lower peripheral speed than the high-performance fan. Noise measurements showed a difference of about 10 phons for the same shaft power, so that the drum-type fan is only about half as noisy as the high-performance fan. The characteristic parameters for the two fans are given in Table I.

From the above, it can be seen that a compact construction can be combined with low running speed and good efficiency. The optimum value of 1·32 for the specific diameter δ corresponds to the values obtained for "high-speed" flow machines (long-bladed axial fans), whereas the optimum value of 0·44 for the specific speed σ is not much greater than that for "slow-speed" machines (long-bladed radial fans).

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SWITZERLAND

Electromagnetic Models for Transformers

By T. HURTER and G. ECKLIN. (From *The Brown Boveri Review*, Vol. 45, No. 9, September 1958, pp. 410–418, 5 illustrations)

THE calculation of transient voltages in transformers presents great mathematical problems, and mathematical analyses are possible only for certain simple cases. Mathematical treatment can nevertheless be of considerable help to the designer, and, with the advent of large calculating machines, progress is being made in this direction. For more complicated problems, however, use is made of models, such as the well-known geometrical model and the electromagnetic model.

The geometrical model is a scaled-down replica of the original transformer, but its success has been limited by two main disadvantages, i.e., the scaled-down time factor and the very low internal capacitances, both of which make measuring difficult and result in large errors. On the other hand, the modified geometrical model, or electromagnetic model, proposed by Abetti in 1953, has the ability to select an arbitrary dielectric constant, rendering the time-scale independent of the length-scale factor. This arbitrary dielectric constant is obtained by using an external capacitance network, made up of discrete values, connected to the geometrical model. The transformer capacitances must, of course, be known, but their calculation is not difficult. The fineness of the network capacitance lumping is governed by the degree of fineness required of the gradient measurements.

It will be recognized that the capacity network reproduces the correct electrostatic coupling in the transformer, while the geometrical scaled-down part of the model provides the correct electromagnetic coupling. The advantages of the combined model over the purely geometrical model are the arbitrary time-scale factor and the high values of the internal capacitances, since these facilitate measurement. However, the well-known mismatch between the resistances of the original unit and its geometrical model is still present in the electromagnetic model, a fact which seems to have been completely neglected in Abetti's original publication*. This results in greater damping of the transient oscillations in these models, compared with the original transformer. In many cases this greater damping should not be overemphasized, because quite often the maximum stresses occur so soon after the wave has been applied that the damping has not had time to exert any appreciable influence. Nevertheless, it is desirable, sometimes even essential, to reduce this mismatch of losses as much as possible. For this reason, a criterion has been established by means of which it is possible to compare the characteristics of high-frequency damping of different model projects. The same criterion can be used in certain cases to correct the measured value of the model's damping.

This article deals mainly with the damping aspect of the electromagnetic model and, as literature dealing with this subject pays little attention to the reduction factor of the magnetic circuit, this question is therefore considered in more detail.

SCALE-FACTOR LIMITATIONS

It can be shown that the scale factors for the geometrical model must fulfil the following conditions:—

* P. A. ABBETI: "Transformer Models for the Determination of Transient Voltages"; *Power Apparatus and Systems*, No. 6, 1953, pp. 468-480.

$$\mu \gamma l^2 = t \quad .. \quad .. \quad .. \quad .. \quad (1)$$
$$\mu \varepsilon l^2 = t^2 \quad .. \quad .. \quad .. \quad .. \quad (2)$$

where l, t, ε, μ, and γ are the scale factors of length, time, relative dielectric constant, relative permeability, and conductivity respectively. The simultaneous conditions (1) and (2) both considerably restrict the choice of scale factors. In practice, the model can only be built of the same material as the original, i.e., $\mu = \varepsilon = \gamma = 1$. In this case, the conditions of similitude (1) and (2) can only be fulfilled when $l = t = 1$.

This implies that the model and original are identical, and defeats the purpose of the model. However, this does not mean that successful models cannot be made. Conditions (1) and (2) apply simultaneously only when it is required to produce both conduction and displacement currents in the model correctly. Fortunately, for most transient phenomena in transformers, the conduction currents (losses) can be neglected, and only condition (2) remains.

For a practical geometrical model, $\varepsilon = \mu = 1$; it can therefore be seen that there is only one independent scale factor ($t = l$). A model scaled down to 1:5 also has the same time-scale factor, and a wave-front duration of 0·2 μsec is quite close to the minimum value that can be applied to a winding by means of a transient analyser. It would therefore be difficult to study the effects of impulses with shorter wave-front durations than the standardized value (1 μsec) encountered in the study of chopped waves.

This difficulty is overcome with the electromagnetic model, since its time scale is independent of the length scale. However, even for this model, both conditions of similitude (1) and (2) remain valid, though naturally ε is now arbitrary and greater than unity, while μ and γ still remain equal to unity. Even with $\varepsilon > 1$, it can be shown that the conditions of similitude (1) and (2) are not simultaneously satisfied; this is also the case for the geometrical model. It is for this reason that both types of models have higher losses than the original. Condition (1) is again neglected for the electromagnetic model, leaving $t = l\sqrt{\varepsilon}$ and $\mu = 1$. By using a capacitance network, ε is arbitrary (though greater than unity), and the time scale is independent of the length scale.

Since the geometrical part of the model only reproduces the electromagnetic characteristics, it is possible to scale the number of turns. The electromagnetic model thus has three independent scale factors, e.g., length, time, and turns.

Damping-Scale Factor

It is recognized that the logarithmic decrement of a damped oscillating circuit is proportional to the ratio of the a.c. series resistance and the reactance of the inductance at the oscillation frequency. The damping-scale factor is defined as the ratio of the logarithmic decrement of the model's winding to the corresponding value for the original. When the damping scale is equal to unity, there is no mismatch of losses between the original and its model. In other words, the damping of transients is identical in both the original and the model. At first sight, it seems impossible to attain this ideal case, since the first condition of similitude cannot normally be fulfilled. It can readily be seen that, as regards losses, this damping-scale factor acts as a figure of merit for the electromagnetic model and can thus be of great help in selecting the optimum model. Knowing the damping-scale factor in terms of independent scale factors, it is possible to design better low-loss models. In the few cases where the measured transient voltage has a very low harmonic content, the damping-scale factor can be used to correct the effect of the model's high losses on the measured maximum amplitudes.

Determination of the damping-scale factor δ is based on the classical method of calculating the a.c. resistance of transformer windings developed by Rogowski. This theory relies on the assumption that the leakage field has only an axial component, and this is the case in practice for long windings in the axial direction having uniform current density. This, of course, is not precisely true of transient phenomena. However, it should be borne in mind that only the a.c. resistance-scale factor (ratio of the a.c. resistance of the original to that of its model) is required, but not the absolute values. The a.c. resistance can be divided into two components, one of which is due to the axial leakage field and the other to the radial leakage field. Both components are in the same proportion in the original winding and the model, so that the ratio of the a.c. resistances due to the axial leakage field is the same as would be obtained by using the values of the total a.c. resistances. The determination of the damping-scale factor can therefore be based on Rogowski's a.c. resistance theory. The damping factor δ for the electromagnetic model was found to be

$$\delta = (n\sqrt{t})/l \quad .. \quad .. \quad .. \quad .. \quad (3)$$

where n denotes the scale factor of the number of winding layers perpendicular to the main leakage field. Losses in the model and the original are matched for $\delta = 1$. If possible, the model should be designed so that δ remains in the neighbourhood of unity. It is interesting to note that the value of δ is independent of the turns-scale factor, but dependent on the way the turns are represented in the model. This may be explained by the fact that, for multilayer windings, the effective copper section of one turn at high frequency depends inversely on the number of layers on the outer side of this turn. A reduction of layers therefore increases the penetration depth and the effective cross-section, leading to lower losses.

From the viewpoint of the measuring technique, the time-scale factor t should not be less than about 1; a high value ($t \approx 10$) would be quite advantageous. However, as can be seen from eq. (3), the time scale, for a minimum loss mismatch, should be as low as possible, the optimum value probably being $t \approx 1$. The choice of l is governed largely by economic considerations, and its value is generally of the order of 1:5. In this case, criterion (3), with $t = 1$, yields $\delta = 5n$, inferring that the damping in the model is five times greater than the value in the original winding, provided that both windings have the same number of layers, as is normally the case.

Layer-winding models must have the same number of layers as the original. However, it is possible with disc windings to choose n so that there is practically no loss mismatch. With $n = 1$, criterion (3) is also valid for geometrical models. Moreover, as $t = l$, for geometrical models

$$\delta = 1/\sqrt{l} \quad .. \quad .. \quad .. \quad .. \quad (4)$$

Comparison between criteria (3) and (4) shows that the electromagnetic model, for its normal values of $n = 1$ and $t \approx 1$, has more damping than the geometrical model. For $l = 0{\cdot}2$, the damping-scale factor δ for the geometrical model is 2·24, compared with 5 for the electromagnetic model. The advantages of the electromagnetic model outweigh this increased damping.

With $\delta = 1$, eq. (3) for the electromagnetic model

becomes $n^2t = l^2$, while eq. (4) for the geometrical model becomes $1 = l^2$. With arbitrary values of t and l, the first condition of similitude can, if necessary, be satisfied for certain electromagnetic models, whereas the incompatibility of the geometrical model remains.

Scale Factor for the Cross-Section of the Iron Core

In order to match the non-linear characteristics of both the original and the model transformers, the cross-section of the iron core must be scaled down so as to provide the same magnetic flux density in the two cores at corresponding times. Moreover, the effective iron section must be geometrically scaled down. These conditions determine the voltage-scale factor. The frequency spectrum of the transients is sufficiently high, so that the effective iron section is determined by the depth of penetration of the magnetic field. Based on these conditions, the iron cross-section scale factor A has been determined as

$$A = l^2 d/\sqrt{t} \quad .. \quad .. \quad .. \quad .. \quad (5)$$

where t, l, and d are the time, length, and lamination-thickness scale factors respectively. In all practical cases, the iron core is built with standardized material; thus, $d = 1$, and $A = l^2/\sqrt{t}$.

With a time scale $t \approx 1$, $A = l^2$, which means that the iron core can be a geometrically scaled model of the same material as the core of the original transformer. Apart from iron losses, it can also be shown that, with $t = 1$, the iron core is correctly scaled for transient phenomena, as well as for power-frequency requirements. A model with the same time scale as the original again seems to be the most advantageous.

It should be mentioned here that, when one winding in the transformer is short-circuited, the iron core plays a very small part in the voltage transients. In such cases, it is possible to build the model without any magnetic circuit, making it simpler and cheaper, but limiting the number of test conditions, one of which is the short-circuiting of at least one winding. However, the scope of this simplified model is often quite adequate. The characteristics of a model without an iron core are independent of the voltage; consequently, the voltage scale becomes arbitrary. Even for models with magnetic circuits it is often possible to assume an arbitrary voltage-scale factor.

Comparison of Transient Voltages in an Original and a Model

Before electromagnetic models were used for transient studies, certain experiments were carried out on a full-size 220-kV, 22·3-MVA disc winding. In order to make a complete comparison between the transients in a full-size and model winding, a simple model of this winding was built. For both sets of windings, the low-voltage secondary was replaced by a short-circuited aluminium shield placed inside the primary winding, outside which was an electrostatic shield. Since the secondary was short-circuited, no iron core was necessary, either for the original or its model. However, in order to confirm this, a magnetic circuit was made for the model and tests were carried out with and without this core.

The model was scaled down to a fifth of the original size. Time, number of layers per disc, and number of turns N remained unaltered, i.e., $l = 0{\cdot}2$, and $t = n = N = 1$. It is worth noting that the d.c. resistance for the model is five times greater than that of the original, compared with the ratio of 1:1 for the a.c. resistance and 1:5 for the reactance. The logarithmic decrement of the model is five times greater than that of the original ($\delta = 5$). For perfect matching of the losses, δ should be unity.

Transient voltages in both the original and its model were measured with a transient analyser. Oscillograms obtained between corresponding points of the original and its model with and without the iron core showed that the electromagnetic model reproduced the voltages in the original winding with good accuracy with respect to time and amplitude. As expected, no detectable difference in amplitude or time was found between measurements made with and without the magnetic circuit of the model. The effect of the greater damping in the model was clearly shown in the oscillograms.

In order to determine the damping-scale factor experimentally, the voltage from the mid-point of the winding to earth was measured with a very long time base. The voltage at this point is fairly sinusoidal after a few microseconds, since the harmonics are quickly damped out. The ratio of the logarithmic decrements of the original to the model is therefore equal to the damping-scale factor. The oscillograms obtained clearly showed the heavy damping in the model. The ratio of the average logarithmic decrements of the original to model obtained from these oscillograms was found to be 4·3, compared with the calculated damping factor of 5·0. Good agreement between the theoretical and experimental values confirms the validity of the calculations used to determine the damping-scale factor.

The average absolute and relative deviations of the maximum voltage gradients between the original and its model, over twenty corresponding points, were found to be 0·027 of the applied voltage and 10% respectively. These figures agree closely with those given by Abetti, i.e., 0·024 and 11%. It was found that the deviation increased with time, this behaviour being consistent with the damping problem. This accuracy of the electromagnetic model can be considered typical and adequate for the design of transformer insulation.

Other models have been built for transformer design purposes. Thus, for example, comparisons have been made between the calculated voltage distribution at a given time in a layer winding, rated at 220 kV, 16,667 kVA, and the measured values obtained from its electromagnetic model, with $l = 0{\cdot}25$, $t = 1$, and $N = 0{\cdot}4$. This model furnished design data which could not be obtained by calculation, owing to the limited validity with respect to time.

Conclusions

Both the electromagnetic and geometrical models of transformers suffer from heavier damping than the original. Also, damping in the electromagnetic model is heavier than in the geometrical model, though this is offset by the advantages of having an arbitrary time scale and high internal capacitances. In most cases, the heavier damping does not detract from the usefulness of the electromagnetic model for the determination of transients. However, with careful design and normal materials, it is possible to construct reliable electromagnetic models having losses comparable with those occurring in full-size transformers.

In short, it may be stated that the electromagnetic model is an excellent aid to designers, as it accurately reproduces transient phenomena in transformers and is therefore conducive to the construction of superior and more economical units.

U. S. A.

The Use of Semiconductors for Strain Gauges

By W. P. Mason. (From *Bell Laboratories Record*, January 1959, pp. 7–9, 5 illustrations)

Of the many materials usually employed as electromechanical transducers in gauges for measuring such quantities as tension, compression, acceleration, pressure, shear forces, and torque, the two most important groups are the piezoelectric materials, in which mechanical motion produces a voltage, and the piezoresistive materials, in which mechanical motion produces a change in resistance. Admittedly, magnetostrictive materials, in which mechanical motion causes a change in a magnetic field which then generates a voltage in a surrounding coil, are another possibility, but they have certain disadvantages which limit their use in many applications, e.g., for measuring force, torque, or acceleration.

With any of these types of materials, the ideal would be to have a device that is very sensitive to small forces, responsive both to static forces and to periodic forces over a wide band of frequencies, operative over a wide range of temperatures and humidities, and stable with time. It is also advantageous if the device can easily be fabricated and is small enough to add only a negligible weight to that of the object being measured. Unfortunately, all these requirements are not met by conventional materials, and there is a definite need for more stable and more sensitive materials capable of operating over wider ranges of frequency, temperature, and humidity. It has now been found, however, that semiconductors meet most of these requirements; in fact, certain semiconductors, hitherto used in the manufacture of transistors and diodes, possess a number of remarkable properties when used in gauges.

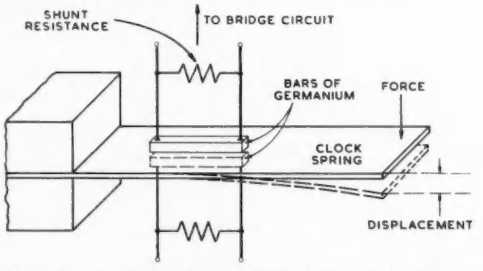

Fig. 1. Arrangement of displacement gauge using crystals of germanium.

Many metals and alloys exhibit a change in resistance with strain, and a length of metal wire, usually the alloy constantan, is the sensing element in the most common types of strain gauges. In the simplest case, the gauge is attached to a long rod and, for stress, weights can be added at the bottom of the rod. With increasing stress, current, when passed through the gauge, changes as a result of the varying resistance of the wire. A bridge circuit is placed across the sensing wire, and a value of strain is read from a calibrated dial.

The sensitivity of such a gauge is described by its gauge factor, which is expressed as dR/RS, where R is the resistance of the unstrained piezoresistive element and dR is the change in resistance with strain S. Most commonly used metal-wire strain gauges have gauge factors between 2 and 4. Somewhat higher values are obtained with platinum wire, and values up to 20 are noted for nickel. By contrast, germanium is so much more sensitive that gauges using this material have factors up to 150, while silicon permits factors as high as 175. In fact, a displacement gauge using germanium has been constructed (Fig. 1) and has proved so sensitive that the factor limiting its sensitivity is the normal vibrations of a building. As a result, a shunt resistance has had to be placed across the germanium, to eliminate the effects of these vibrations and, even then, the device is still about fourteen times as sensitive as the conventional wire-type gauge. With mounts that are resistant to shock and vibration, the full sensitivity (about eighty times that of a wire gauge) can be realized.

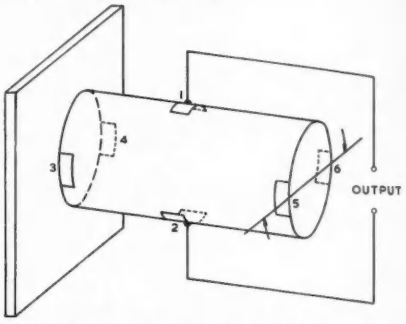

Fig. 2. Configuration of a torsional transducer using a cylindrical crystal of germanium.

It will therefore be appreciated that germanium, silicon, and other semiconductors make it possible to construct strain gauges which are about two orders of magnitude more sensitive than other types. This is, however, only one of their advantages, as, in addition, semiconductors can measure static and low-frequency stresses, as well as high-frequency stresses up to the resonant frequency of the material.

In these new gauges, stress forces can be quite large, since semiconductors are generally strong materials. They can also be used to measure hydrostatic forces merely by immersing the gauge in the fluid. Furthermore, since most semiconductors are structurally and chemically stable, their characteristics should not change appreciably with age or under conditions of high humidity. Operating temperatures with germanium range up to 600°K, and with silicon to 1000°K, these limits being set by the " intrinsic " temperatures of the elements, above which they lose their piezoresistive characteristics. Above the intrinsic temperature, thermal agitation is the main cause of resistivity and is not affected by stress. Certain intermetallic semiconductors, like gallium arsenide, with an intrinsic temperature of 1400°K, should be even better in this respect.

These semiconductor crystals have another advantage not possessed by wire-type gauges, i.e., they respond to torsional and shearing forces and thus can be used directly to measure torque. The configuration of such a torsional transducer, constructed at the Bell Telephone Laboratories, is shown in Fig. 2. Basically, this device comprises a cylindrical crystal of germanium, 0·13 in. in diameter and 0·50 in. in length, cemented to a solid support at one end, with electrodes (1) to (6) attached, as shown. With a proper biasing voltage, current is caused to flow from electrode (3) to electrode (5), and from electrode (6) to electrode (4). Electrodes (1) and (2), attached midway

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Apparatus for Testing the Solderability of Wire

By J. A. TEN DUIS. (From *Philips Technical Review*, Vol. 20, No. 6, 1958/59, pp. 158–161, 6 illustrations)

THE connections between components in electrical apparatus are usually made by soldered joints which, particularly in mass production, must be effected quickly and reliably. The solder must therefore rapidly and thoroughly wet the metals to be joined.

For the general investigation of solderability, wide use is made of what is known as the "spread" test, various versions of which are practised. In one example of such a test, a measured quantity of solder is placed, together with a suitable amount of flux, on a square sample plate of the metal to be soldered. This small plate is then heated by floating it on a bath of molten solder kept at constant temperature. When the solder on the plate melts, it wets part of the surface, the size of the patch wetted depending on the conditions. Approximately 15 sec after beginning to melt, the solder has usually stopped spreading. The area of the patch wetted after this time is taken as a measure of solderability under the conditions of the test.

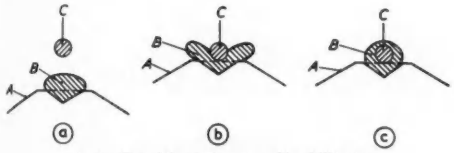


Fig. 1. **Principle of the new solderability test.**

The spread test is well adapted for investigating the conditions favourable for dip-tinning in a bath of molten solder. However, the test does not so readily allow conclusions to be drawn with regard to the joining of wires by dip-soldering or by soldering-iron work. A drawback in this respect is that the spread time of 15 sec is long, compared with the time of about 2 sec common for work with the soldering-iron. Thus, for example, if a flux consisting of pure rosin with 10% ureum in alcohol is used, the solder will initially spread more quickly than it does with a flux consisting of a solution in alcohol of pure rosin only. This favourable result is not, however, revealed by the results of the spread test, which actually indicates pure rosin to be the better of the two fluxes. This erroneous conclusion is even more evident when pure rosin in alcohol is compared with a more active flux consisting of hydrazine hydrochloride in water. Furthermore, in many cases the spread test fails to reveal the effect, generally favourable, of a higher soldering temperature. The correlation between practice and the results of such tests is therefore not very good.

Attempts have been made to overcome these drawbacks by measuring the wetted area after shorter intervals, while spreading is still in progress. Apart from photographic methods, which are rather cumbersome, all the methods hitherto proposed have been lacking in accuracy. A further disadvantage of the spread test is the somewhat lengthy procedure of determining numerically the size of the moistened area. Moreover, this form of test is obviously far from ideal when the metal to be soldered is in the form of wire, as is usually the case in the electronics industry, where the most common components have wire connections.

To overcome these disadvantages, a method specially adapted for testing the solderability of wire has been developed by Philips. In this method, the measure of solderability is taken as the time needed for a drop of solder to flow entirely around a wire of the metal under investigation. The principle of the test is illustrated in Fig. 1. In a small hollow in a block *A* of chromium-plated chrome-nickel steel (the soldering block), a measured quantity of the solder is introduced (Fig. 1a). The exact quantity is obtained by punching a pellet out of a bar of solder rolled to a certain thickness. The soldering block is electrically heated and, when the solder has melted, it remains in the hollow in the form of a globule *B*, as solder does not wet chromium. The wire *C* to be investigated is clamped centrally above the globule of solder, after previous dipping in the flux. The soldering block is now raised, so that the wire cuts the drop of solder in two (Fig. 1b), the two halves creeping up round the wire at a speed which depends on the conditions. When they come into contact at the top of the wire, they flow together with an abrupt movement (Fig. 1c). The instant at which this happens can be observed very precisely. The time elapsing between splitting of the globule and flowing together at the top of the wire is measured with a stopwatch. The shorter this period, the better is the solderability. The results show very good correlation with practice.

The temperature of the globule is measured with a mercury thermometer, inserted into a cavity in the soldering block. The correction to be made for the thermometer reading is ascertained by replacing the solder on the block by salts of known melting point.

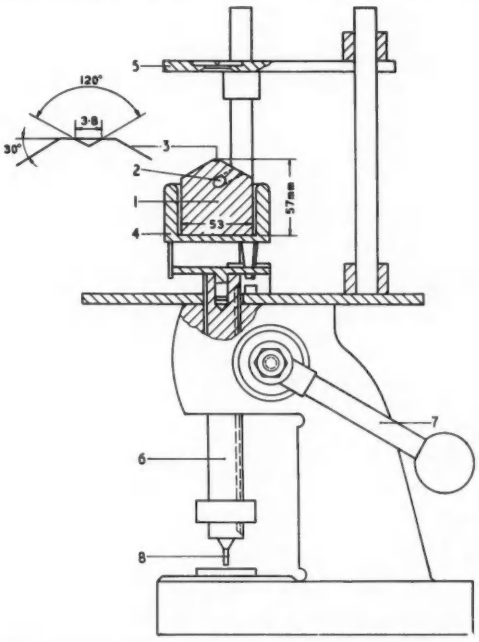


Fig. 2. **Schematic arrangement of the apparatus for testing the solderability of wire.**

(1) Soldering block; (2) hole for thermometer; (3) hollow for solder droplet; (4) heater jacket; (5) wire holder; (6) plunger; (7) lever for raising soldering block; (8) tool for punching solder pellets.

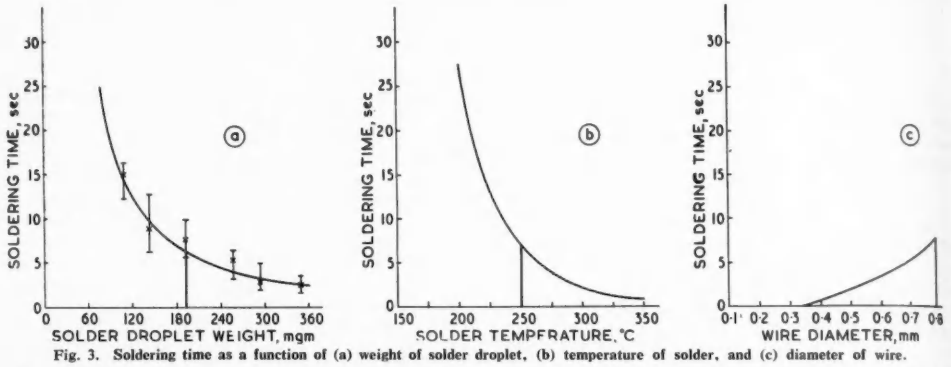


Fig. 3. Soldering time as a function of (a) weight of solder droplet, (b) temperature of solder, and (c) diameter of wire.

The construction of the apparatus is illustrated schematically in Fig. 2. To ensure that the results obtained with different units of this type are comparable, it is essential that they should all be identical in certain features. Thus, for example, the dimensions given in Fig. 2 for the hollow containing the globule must not vary, as these dimensions determine the height of the globule, which should be constant, inasmuch as a higher globule, for instance, will flow more rapidly around the wire. With the dimensions given and with a globule of solder weighing 190 milligrams, the apparatus is suitable for testing wire from 0·5 to 1·0 mm diameter.

The other dimensions of the soldering block and the material of which it is made influence the supply of heat to the globule, whilst the length of the wire and the way in which it is clamped affect the dissipation of heat. Consequently, with regard to these points, individual instruments must also be closely identical.

Factors Influencing the Soldering Process

Using this test method, an investigation has been carried out into the influence of various factors on the soldering process, the principal factors being (1) composition and quantity of the solder, (2) composition and quantity of the flux, (3) composition and surface state of the metal to be soldered, and (4) temperature.

The investigation was prompted by the need for greater control of the dip-soldering process as used for printed wiring. In this process, all connections between the mounted components and the printed wiring are simultaneously soldered by dipping in a bath of molten solder. In hand-soldering with a soldering-iron, any difficulty in soldering particular wires can usually be overcome by suitably raising the soldering temperature or by applying a more active flux. In the dip-soldering of printed wiring, the difficulties are much greater, as often the base cannot be subjected to too high a temperature without the printed wiring becoming loose, and there is a considerable risk that a highly active flux may creep and create leakage paths. These considerations impose more stringent requirements on the solderability of the connecting wires.

The investigation was designed around certain fixed conditions, one of the variables being changed at a time for each experiment. The fixed conditions were chosen with a view to obtaining a soldering time that was not so short as to make the influence of favourable factors scarcely perceptible. The solder used consisted of 60% tin and 40% lead, and the solder globule weighed 190 mgm, corresponding to a volume of 22·4 mm^3. The flux comprised 40% by weight of pure rosin and 60% by weight of alcohol, applied to the wire by dipping. The temperature was 250°C, and the wire was of copper, 0·8 mm in diameter, degreased successively in trichlorethylene and acetone. The average "soldering time" under these conditions was about 7 sec.

Very favourable conditions yielded times shorter than 1 sec. The effects of variations in the quantity of solder, the temperature, and the wire diameter can be seen in Fig. 3. The crosses in Fig. 3a are the averages for ten experiments, the spread in the observations being also shown. It is true that there is a fairly wide spread in the results, but the averages of the ten tests for each measuring point lie reasonably well on the curves. Since each measurement takes little time, it is practicable to make a number of repeat observations under the same conditions.

A slight change in the composition of the solder can cause a marked change in soldering time. For example, the addition of 1% cadmium or zinc lengthens the soldering time to more than 30 sec. On the other hand, the addition of 1% silver has a slight shortening effect. With a pure tin solder, the soldering time is over 30 sec.

The experiments on the influence of the solder composition were repeated at a soldering temperature of 300°C, the soldering times being found to be fairly short and the differences less marked. With printed wiring, however, low-temperature soldering is necessary, and in this case the composition of the solder is of importance.

As regards the composition of the flux, it was found that the concentration of the pure rosin solution must be at least about 25% if it is to be applied by dipping. With rosin concentrations of 20% the soldering time was frequently in excess of 30 sec. Increasing the content from 25% to 40% gives hardly any further improvement. The addition of a quantity of ureum equal to 10% of the quantity by weight of pure rosin reduces soldering times to less than 1 sec. The same short times are obtained with solutions of the monohydrochloride or dihydrochloride and monohydrobromide or dihydrobromide of hydrazine in water. Owing to their rapid decomposition, the concentration of these four compounds has a definite lower limit. The limiting concentration for the first three lies at about 3%, and for the fourth at about 2·5%; at these concentrations, soldering times shorter than 0·1 sec, as well as longer than 30 sec, are found. The best results with zinc chloride are found for an approximately 10% solution in water, the average soldering time then being 1·2 sec.

The composition of the metal to be soldered and the

(*Concluded on page 82*)

Improved Metal Detection Equipment

By T. G. CHARLES. (From *ASEA Journal*, Vol. 31, No. 7, 1958, pp. 98–105, 9 illustrations)

In 1954, details were given of a new type of simple and sensitive metal detector, specially intended to fulfil industrial requirements.* Since then, this detector has been further developed and simplified, and the new version, designated the "Asdet", is now in full production.

Most existing metal detectors use the balanced-coil principle, which requires great accuracy of balance for high sensitivity. As a result, they are inherently unstable, and manual rebalancing is necessary. Also, for various reasons, the working frequency is fixed, limiting their range of application to relatively inert materials. The principle of the Asdet is fundamentally different, in that detection is performed by measuring the transient change of the magnification factor Q of a tuned circuit. As this tuned circuit consists of both an inductance and a capacitance, either of these may be used as the search element, opening up a much wider field of application than has hitherto been possible. By artificially restricting the amplitude of the oscillations, sensitivity has been increased several hundred times, compared with the sensitivity of a free-running oscillator.

It is well known that a cathode-follower, i.e., an amplifier where the output is taken from the cathode instead of from the anode, possesses excellent stability, but has an amplification which is always less than unity. Thus, it cannot be used as an oscillator of conventional design. A resonant circuit can, however, give a voltage amplification in proportion to its Q-value, if the input and output circuits are correctly arranged. This is the basic principle of the Asdet oscillator, where Q-dependent voltage amplification is provided in the tuned circuit which forms the search-head, whereas the valve provides power amplification only.

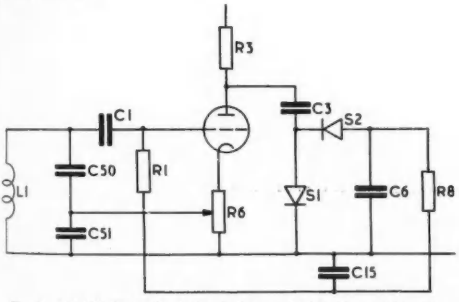


Fig. 1. **Modified circuit of the Asdet metal-detection equipment.**

This design enables a considerable simplification to be made. The previous two double triodes are replaced by a single sub-miniature pentode and, in spite of this simplification, performance has been found to be greatly improved. The basic circuit is shown in Fig. 1, in which L1 and C50 form the resonant circuit, as before. An additional capacitor C51 is added, across which the output voltage from the cathode-follower is applied. In practice, C51 is so much larger than C50 that it has negligible influence on the resonant frequency of the circuit. The voltage applied to C51 may be varied by means of the variable resistor R6; this control is called "Q-compensation" in the equipment and is fitted so that the loop gain of the circuit may be adjusted to unity, even though coils having widely differing values of Q are used. The voltage applied to C51 is amplified by the tuned circuit and applied to the control grid of the valve.

The operational output voltage is taken from the anode of the valve. Besides giving a much higher voltage than appears at the cathode, this method has the great advantage that the operational side of the circuit is completely isolated from the oscillator part. The output voltage is rectified in a voltage-doubling circuit and the resultant d.c. voltage is applied to the control grid as an automatic control voltage after a suitable time-delay by means of R8 and C15. The resulting control of amplitude is very good and is almost entirely independent of all reasonable changes in valve characteristics, etc. For example, the heater voltage, normally 6·3 V, can be reduced to 4·0 V without any measurable change in amplitude or sensitivity.

An idea of the sensitivity of this simple circuit may be obtained from the fact that the change in the Q-value of the search-coil necessary to produce a 10% reduction in the output voltage (sufficient to operate the relay) is only 1 part in 100,000, corresponding to a metal particle having a diameter equal to 1% of the coil diameter. The gain and phase-shift characteristics of the oscillator are excellent and enable frequencies to be used from 3 kcs to 0·5 Mcs without any alteration except for adjustment of R6 to compensate for different Q-values in the coils.

The circuit has been designed to operate at low voltages and currents without impairing performance. This has resulted in a great simplification in the power supply unit, which uses a constant-voltage transformer of the saturated-core type, supplying stabilized voltage to the rectifier, as well as stabilized voltage for the valve heaters. The use of stabilized heater voltage is not common practice, but has two advantages in that the stability of the apparatus as a whole is improved and also valve life is increased. After rectification by means of a selenium rectifier, the anode supply is filtered by means of a 2-stage RC-filter and stabilized by means of a neon stabilizer. The total consumption is about 15 mA at 85 V. Thus, all components in the Asdet are very lightly loaded.

A sub-miniature valve of the tuning-indicator type has been introduced to simplify setting up the equipment, obtaining rapid and accurate setting of the Q-compensation adjustment. It is in use for only a few minutes, either when setting up the equipment initially or after changing the oscillator unit, and is brought into operation by means of a spring-loaded push-button. Under continuous operation, the temperature rise in the equipment case is about 30°C, the maximum permissible ambient temperature being + 55°C. Normally, the equipment is operational approximately 5 min after switching on, but, if the temperature of the case and its contents is below — 30°C, the warming-up time should be increased to 20 min. For temperatures between — 30°C and 0°C, the time is proportionally less.

Basically, the Asdet comprises a case and a search-head, connected together by a coaxial cable, which may be up to 50 ft in length (in special cases, 330 ft). After installation, all that is necessary is to adjust the Q-compensation control, an operation which takes from 1 to 2 min, and then to set the sensitivity and time-delay controls. It should be appreciated that a particular advan-

* T. G. CHARLES: "Industrial Metal Detectors"; *ASEA Journal*, No. 4, 1954, pp. 55–64; also, *The Engineers' Digest*, No. 9, 1954, page 388.

tage of this equipment is that the case is a standard item and it is only the search-head which is altered to suit different requirements.

The equipment will operate over a frequency range of over 100:1 without any modification whatsoever, and the operating frequency is decided within this range by the search-head alone. This wide latitude in working frequency enables better detection to be carried out on normal materials, as well as detection in cases which are generally considered impossible.

When it is required to detect metal in a material, the search-head always consists of a coil as the active element and a pair of capacitors to tune the coil to the desired frequency. All are then cast into a hard plastic material, giving high mechanical strength and impermeability to moisture.

Design of Search-Coils

The design of the search-coil is basically dependent on two factors, i.e., the size of the coil and the working frequency. The size of coil is often determined either by the size of material to be inspected or by the mechanical handling arrangements. There are, however, a number of factors to be taken into account, of which perhaps the most important is that sensitivity bears a fixed relationship to the size of the coil. This means that, if it is required to detect particles of a certain size, there is a certain maximum coil with which this can be effected, and with a larger coil these particles can never be detected. In the case of powders and similar materials, the aperture can be reduced and the velocity increased to cope with a given bulk of material.

The maximum sensitivity is usually that corresponding to a figure of merit of 100, i.e., the smallest detectable particle has a diameter equal to about 1% of the coil diameter. Sensitivity is modified to some extent by frequency, the velocity of the particle passing the coil, and the shape of the coil. If the material to be inspected is dry and non-conducting, the optimum frequency for detecting metal may be used, and the smallest particle detected will be about 1% of the coil diameter. If the coil is not circular, the equivalent diameter for calculating purposes may be obtained by computing the diameter of a circle having the same peripheral length as the coil in question. This rule of thumb does not apply, however, to coils having a ratio of length to breadth greater than 6:1.

If the velocity of the material passing the coil is too low, the automatic gain adjustment comes into operation and greatly reduces sensitivity. This rapid reduction in sensitivity occurs at velocities below that equivalent to about a quarter of a coil diameter per second. Owing to the Q-factor of the coil, a much more gradual fall-off in sensitivity occurs at high velocities. This commences at a velocity equivalent to three or four coil diameters per second, sensitivity being approximately halved at a velocity equivalent to ten coil diameters per second. For special applications it is possible, by removal of certain components, to obtain an almost unlimited upper velocity, but at the expense of losing certain "material-distinguishing" properties.

The choice of frequency is rather more involved. The problem can be simplified into one of obtaining the maximum signal from the metal particle (maximum change in the Q-value of the coil) while obtaining no signal from the material being inspected. In the case of a dry non-magnetic, non-conducting material (flour, tea, cement, etc.), no problem arises, since such a material will not produce any signal, and the frequency can be chosen according to the size of the smallest particle to be detected.

It is well known that high-frequency fields do not penetrate to an unlimited depth in a conducting material. This penetration is characteristic of the material and the frequency, and is called depth of penetration or skin depth. Tests have shown that in a given coil the greatest reduction in the Q-value occurs when the frequency is such that the depth of penetration is half the particle diameter. Thus, if the properties of the material under inspection may be neglected, the working frequency is decided by the minimum size of metal particle to be detected. Two very important points arise: Firstly, it must not be thought that, if the Asdet will detect a small particle, it might not detect a larger particle. The reason is that increasing the diameter of the particle increases ΔQ much more than departure from the ideal frequency decreases ΔQ. Secondly, because of its principle of operation, the Asdet has a sensitivity less dependent on the resistivity of the metal particle than is the case with other types of detector, in which the out-of-balance signal produced is proportional to the conductivity of the particle. In the Asdet, this signal is proportional to the diameter divided by the depth of penetration, and, to illustrate its advantage, it may be mentioned that the ratio of conductivities of copper to stainless steel is 58:1·4, whereas the ratio of diameter to depth of penetration at the optimum frequency is only 5:7·2, i.e., the variation in sensitivity for different materials is reduced by a factor of 28. In many cases it is not possible to disregard the material being inspected when choosing the working frequency, and in such circumstances it is necessary to use a frequency other than that determined by the size of particle and the depth of penetration.

In the Asdet, ΔQ is proportional to μ/ρ', where μ is the permeability of the material and ρ' the apparent high-frequency resistivity, taking into account the effect of skin depth. For all non-magnetic materials $\mu = 1$ approximately, and ΔQ simplifies to $1/\rho'$. In the case of a dry non-conducting material, ρ' is very high, and thus ΔQ is very small, i.e., the material is not detected.

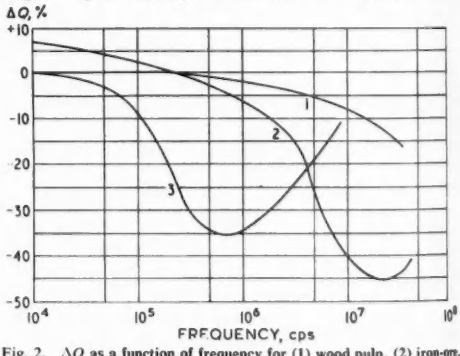


Fig. 2. ΔQ as a function of frequency for (1) wood pulp, (2) iron-ore, and (3) copper pyrites.

Despite the fact that the relationship between ΔQ and frequency is determined by μ/ρ', three types of material occur in practice, and examples of these are plotted in Fig. 2, which shows typical curves of ΔQ as a function of frequency for wood pulp, iron-ore, and copper pyrites. In curve (1) for wood pulp, it can be seen that the losses increase with frequency. If the wood pulp must not be indicated, a low working frequency must be chosen, but not so low that sensitivity to metal is reduced. In curve

(2) for iron-ore, the presence of magnetic material produces positive values of ΔQ at lower frequencies but, as frequency is increased the eddy-current losses nullify this positive change and ΔQ becomes negative. If the conducting particles in the iron-ore (an inhomogeneous material) were very small, no negative values of Q would occur at any usable frequency. The most suitable working point is $\Delta Q = 0$. In curve (3) for copper pyrites, a marked maximum negative value of ΔQ occurs, which is also due to the inhomogeneous nature of the material.

The working frequency is decided by the minimum particle to be detected, and in some cases by the material being inspected. Curves of ΔQ as a function of frequency have been plotted for several hundred different materials, and these curves, together with nomograms of particle size, are used to decide the most suitable frequency.

Practical Applications

The Asdet is suitable for the inspection of a wide range of materials, typical applications being the protection of crushers in mining operations, the prevention of metallic contamination in food and similar products, and the detection of tramp metal in reclaimed materials.

In operation, the case of the equipment is located at any convenient spot, and the search-coil at the point where inspection is required. When choosing this point, it is important to bear in mind that stationary metal near the coil will not impair operation, provided that this metal does not form a shorted turn closely coupled to the coil. If the metal is moving, greater care is needed. Conveyor rollers and similar symmetrical bodies can be regarded as stationary; moving metal objects very much larger than the coil should be at least three coil diameters away, but smaller objects may be proportionately closer.

The most usual application is to pass the material to be inspected through the coil. Sensitivity is a minimum in the geometric centre of the coil, and it is this sensitivity which is always quoted. Sensitivity near the edge of the coil will be 3 to 4 times greater. Another method of mounting the coil, sometimes of convenience where it is not desired to cut a conveyor belt to pass it through the coil, is to mount the coil above or below the belt, with its plane parallel to the conveyor. The price paid for this simplification is a drop in sensitivity, but in the majority of cases sensitivity is still high enough in practice.

Several different types of standard coil have been produced, the majority of which are for conveyor application. All these coils may be mounted around, above, or below the belt, as desired. Conveyor coils are available for 24, 36, 48, and 54 in. belts. A further series of standard coils with rectangular apertures covers a range between 2·3 × 6·3 in. and 12 × 20 in.

It is recommended that a hinged deflector plate should be located a short distance after the coil. This plate normally allows the material to pass on but, if a metal particle traverses the coil, it is deflected electromagnetically or pneumatically via the relay in the Asdet, and the contaminated material is diverted into a separate hopper.

RUSSIA

Automatic Feed Mechanism for the Centreless Grinding of Taps

By V. A. Povidailo and R. I. Silin. (From *Stanki i Instrument*, No. 11, 1958, pp. 23–24, 4 illustrations)

An automatic hopper feed device, for use in conjunction with a centreless grinding machine, has been developed in Russia for the automatic plunge-grinding of tap shanks.

As shown in Fig. 1, components, charged into a hopper (1), slide down an incline to a drum (8), which is fitted with blades (9) on its inner cylindrical surface. These blades take components from the batch and deposit them on a tray (10), which is inclined at 10 deg. to the horizontal, i.e., at less than the angle of friction of the components themselves, so that the latter will not slide down the tray when it is at rest. On vibrating the tray longitudinally, the components move uniformly at a speed which depends on the frequency and amplitude of vibrations.

The centre of gravity of each tap is roughly at the division between the shank and the tapping section. While the components are moving along tray (10), any which have fallen out of position soon overbalance, and it is necessary to remove all which have landed with the shank pointing backwards instead of forwards. This operation is carried out by providing in the tray a slot shaped to the profile of a tap lying with its shank backwards. Any component which falls shank forwards onto the tray passes freely over this slot and over a flap (11), hinged under the slot and supported by a weak spring (12), and reaches a magazine (15). On the other hand, any component which falls shank backwards drops into the slot, opens the flap, and falls back into drum (8).

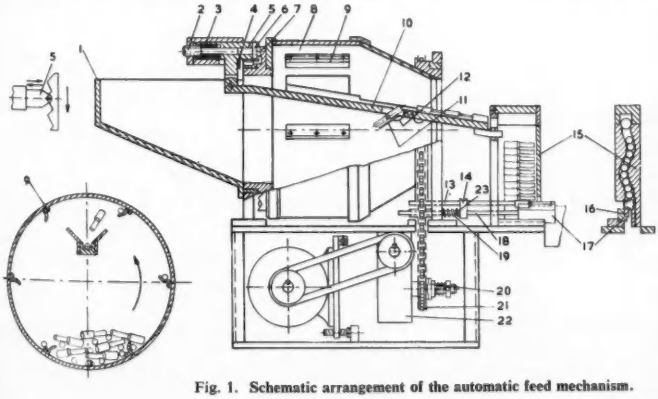


Fig. 1. Schematic arrangement of the automatic feed mechanism.

Special provision is made to vibrate tray (10) longitudinally. The rim of a disc (7) is provided with teeth, against which a slide (5) of the vibrator, with rotating

rollers (6), is forced by means of a spring (3), regulated by a screw (2). On rotating disc (7), the teeth force the vibrator slide (5) and also the tray to describe a vibratory motion. At the end of the forward path, slide (5) strikes against a rubber buffer (4) on the fixed frame, thus increasing the speed of the components, which slide along the tray as a result of their inertia, the distance moved being controlled by the thickness of buffer (4).

The hopper drum (8), rotating at 15 rpm and giving a feed of 30 components per minute, is driven by a 250-W electric motor through a V-belt drive, a reduction gear (22), a clutch (20), and a chain drive (21). Components are fed from the magazine to the working area by a feeder (13), which is a hardened cylindrical rod guided in the hopper frame and the magazine. A carrier (14), fixed to the feeder (13), is fitted with a longitudinal groove, in which is inserted the follower of a lever set in motion by a cam on the spindle of the regulating wheel of the grinder. Carrier (14) can be positioned along the length of the feeder rod (13), thus altering the amount of movement of the tap from the magazine, depending on its length.

A rod (18) passes freely through carrier (14), with a slide (17) resting against its end. This slide carries a support blade (16), which is necessary to guide the tap as it moves towards the grinding wheel and to prevent it from tipping until grinding has commenced. A spring (19) holds a ring (23), fixed to rod (18), against the carrier and, when the carrier begins to move forward, the spring (19) also causes the slide (17) and the support blade (16) to move. At a distance of 3 mm from the grinding wheel, the slide (17) comes to rest against a projection on the blade (16). Feeder (13), however, continues to move and feeds the component between the grinding wheels to a work-rest.

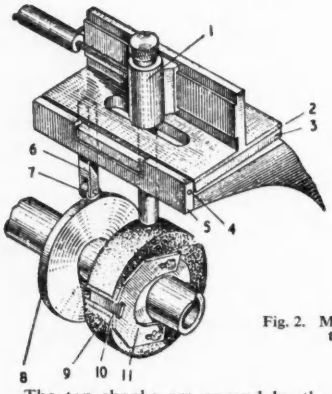


Fig. 2. Method of form-truing the wheel.

The tap shanks are ground by the plunge-grinding method, the regulating-wheel headstock being kept stationary. Cross-feed is obtained by means of a specially shaped regulating wheel, in one revolution of which the entire grinding cycle takes place. For this purpose, the periphery of the regulating wheel is divided into five sectors, i.e., (1) a cylindrical loading sector of 25 deg., (2) a rapid workpiece feed of 10 deg. (Archimedean spiral), (3) a working feed of 250 deg. (Archimedean spiral, 0·2-mm pitch), (4) a circular sizing sector of 45 deg., and (5) an unloading sector of 30 deg. (a transverse gap in the wheel).

The method of form-truing the wheel is shown in Fig. 2. The dressing tool (1) on the machine, with a guide-bracket (2), is fixed to a plate (3), which can be tilted about a pin (4) attached to a rigid bracket (5). By means of the plate (3), a fork (6), and a roller (7), the dressing tool is swung to correspond with the master (8), which is mounted alongside the regulating wheel (9), so that the latter is profiled to match the master.

For grinding components, a tap from the magazine is fed to the loading sector of the regulating wheel, as mentioned above, and is then brought up to the grinding wheel, ground, and sized; during sizing, the tap completes from 3 to 4 revolutions without cross-feed. When the gap in the unloading sector of the regulating wheel comes opposite the supporting surface of the blade, the component slides into the gap and is removed from the grinding wheel to the unloading tray. To ensure that the depth of the gap in the unloading sector of the wheel is not altered during dressing, the gap contains a metallic insert (10) with a profiled notch. This insert is attached to an adjustable plate (11) for compensation of wheel wear. In addition, as the insert is longer than the gap, it prevents the tap from tipping prematurely into the unloading tray and also absorbs the shock of the tap when it rolls from the support blade.

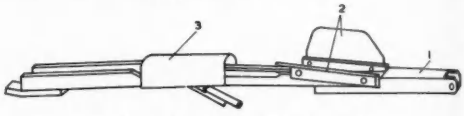


Fig. 3. Detail of one of the hopper trays.

On this automatic machine, the shanks of twelve different standard taps can be ground. The hopper is provided with four interchangeable trays, one of which is illustrated in Fig. 3. The tray is fitted with an arm (1) for attaching it to the vibrator and, to improve the supply of taps, catcher wings (2) are incorporated. The sorting device is covered by a shield (3), preventing any accidental pick-up of components which might otherwise occur. Replacement of the feed mechanism takes from 10 to 15 min and comprises substitution of the trays and alteration of the distance between the faces of the magazine slot by means of distance-pieces. It may also be necessary to alter the travel of the feeder rod (13) in Fig. 1.

Apparatus for Testing the Solderability of Wire

(*Concluded from page 78*)

condition of the metal surface are extremely important factors. It is well known that thin coatings of certain metals, such as tin, applied by electroplating or by hot-dipping to copper wire can greatly improve solderability. However, moisture on the surface, and, in particular, heating of the wire, e.g., 2 hr at 190°C for the stove-enamelling of painted parts, can reduce this effect and make the solderability of tinned wire considerably poorer. Less trouble in these respects is obtained with hot-dipped coatings of tin-lead (50% Sn, 50% Pb) and electroplated layers of tin-zinc (80% Sn, 20% Zn). The spread in the results of temperature and moisture tests is often greater for hot-dipped than for electroplated coatings.

It should be noted that a soldering block of aluminium was used for this investigation. Because of its harder wearing properties the chromium-plated chrome-nickel steel block, already mentioned, was later adopted for routine tests.

A New Method of Detecting Welding Stresses

By W. RÄDEKER (From *Schweissen und Schneiden*, Vol. 10, No. 9, September 1958, pp. 351–358, 12 illustrations.)

THE dangers of brittle fracture and stress corrosion are increased by internal stresses due to welding. Usually, however, these internal stresses cannot be checked on components in service but only on simple testpieces and, even then, known methods of analysis are complicated. This article therefore suggests a practical method which, though only approximate, is simple and cheap and which is based on the fact that cracks due to stress corrosion propagate more rapidly under a higher tensile stress. Only ferritic/pearlitic steels of the types listed in Table I are considered in this instance.

A tensile testpiece exposed under constant load to a corrosive medium shows corrosion cracks propagating gradually into the material at a rate depending on the applied stress, until finally the remaining cross-section breaks statically under the load, mostly without noticeable deformation. If the time between loading and fracture is called the " life " of the testpiece, then it is found that life is affected in the following ways :—

(a) Life increases with decreasing tensile stress, the relation between the two quantities appearing as a straight line in a double logarithmic graph.
(b) Life increases with decreasing concentration and/or decreasing temperature of the corrosive agent.
(c) Life depends on the alloying content and method of production of the steel under test, a steel of higher strength having a longer life.
(d) Life depends on heat treatment. For example, under otherwise equal conditions, an aluminium-killed steel has its longest life after annealing at 750°C, and its shortest life after annealing at 1050°C.

TABLE I : COMPOSITION OF STEELS INVESTIGATED

Steel No.	Type	Composition [%]									
		C	Mn	Cu	Cr	Al	Ni	Si	P	S	N_2
1	Rimming converter steel	0·10	0·45	0·05	0·04	—	—	—	0·042	0·020	0·010
2	Rimming open-hearth steel	0·12	0·47	0·17	0·05	—	—	—	0·014	0·021	0·003
3	Rimming steel	0·03	0·06	0·25	0·03	0·002	—	—	0·007	0·018	0·005
4	Silicon-killed open-hearth steel	0·12	0·53	—	—	0·003	—	0·25	0·023	0·012	0·005
5	Steel for oxygen cylinders	0·40	0·98	0·22	0·14	0·010	0·07	0·24	0·033	0·010	0·004

Consequently, if the temperature and concentration of the agent are kept constant, and comparative tests are taken on the same steel treated in the same manner, it can be assumed that the lengths and the number of visible cracks will increase with increasing tensile stress. For the detection of internal stresses it has proved most advantageous to boil the testpieces in a 60% calcium-ammonium-nitrate solution. The cracks produced during boiling are then at right-angles to the internal stresses. Since the cracks are often too small to be observed by the naked eye, the testpiece may be deep-etched for 24 hr in 50% hydrochloric acid at room temperature or for 30 min in 33% sulphuric acid at 70°C ; alternatively, magnetic crack detection may be used. All the testpieces illustrated in this article have been deep-etched.

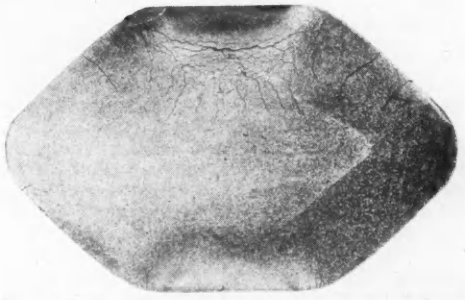
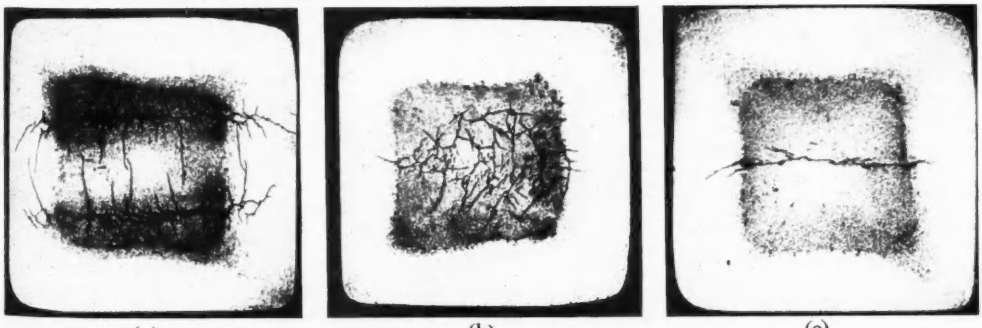


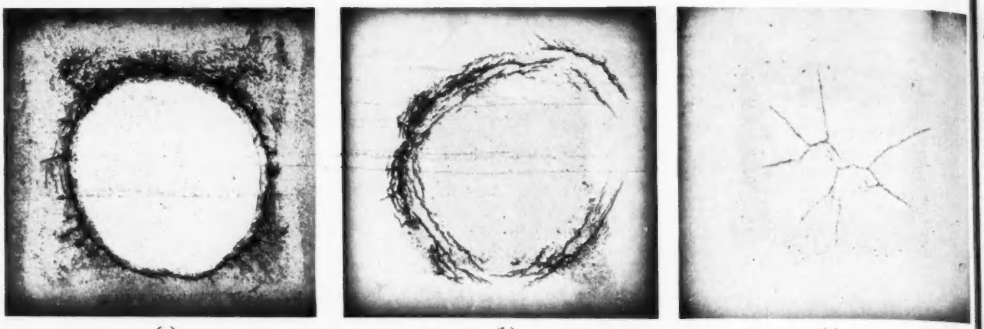
Fig. 1. Stresses in a rectangular steel plate compressed diagonally.

Fig. 1 shows the internal stress distribution in a piece of steel, 15 mm in thickness, cut and machined to shape from a slab of steel No. 3 in Table I, and mechanically compressed by 15 mm in height from 85 mm down to 70 mm. The undeformed testpiece showed no cracks, whereas the cracks illustrated in Fig. 1 in the compressed piece after boiling in the nitrate solution indicate radial and concentric circumferential tensile stresses around the compression " plug ", as well as tensile stresses around the oblique edges. The cracks appear only in the top portion, as the piece was slightly inclined in the press.



(a) (b) (c)

Fig. 2. Effect of local heating along a horizontal line on steel plates, 120 mm square, showing (a) the heated side of a plate of 10 mm thickness, (b) the reverse side of a plate of 10 mm thickness, and (c) the reverse side of a plate of 20 mm thickness.



(a) (b) (c)

Fig. 3. Plates with a weld deposit on one side, showing (a) the welded side of a plate of 10 mm thickness, (b) its reverse side, and (c) the reverse side of a plate of 30 mm thickness.

Local heating may cause very appreciable internal stresses. Thus, tests were carried out with an acetylene flame passed along a central line from right to left over one side of a plate of 10 mm thickness and of another plate of 20 mm thickness, both cut from a rolled slab, 120 mm square. The heated side of the 10-mm plate (Fig. 2a) indicates, after boiling in the nitrate solution, relatively small longitudinal stresses, characterized by transverse cracks, while the stress distribution on the reverse side (Fig. 2b) is more uniform. On the reverse side of the 20-mm plate (Fig. 2c), only a central longitudinal crack appears, so that the maximum value of the transverse stress has moved to the centre of the heated path.

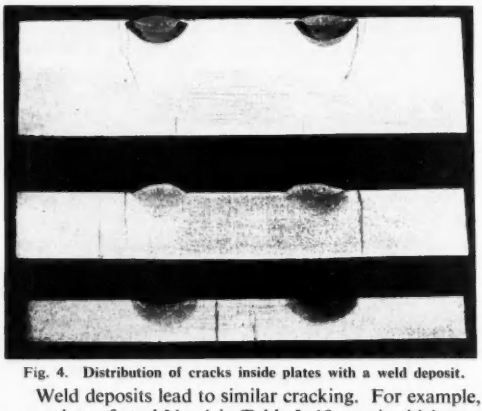


Fig. 4. Distribution of cracks inside plates with a weld deposit.

Weld deposits lead to similar cracking. For example, on a plate of steel No. 1 in Table I, 10 mm in thickness, the deposit itself shows no cracks (Fig. 3a), but considerable radial stresses (and also, to a smaller extent, circumferential internal stresses) are produced around the deposit. The reverse side of the plate (Fig. 3b) shows considerable radial stresses, as indicated by circumferential cracks. On the other hand, the reverse side of a plate, 30 mm in thickness, subjected to similar treatment shows a star-like crack distribution (Fig. 3c), so that radial stresses must have been almost absent. The stress distribution in depth is shown by sectioning of the plates (Fig. 4).

Systematic Tests

Systematic tests were carried out to determine the optimum form of testpiece and the effects of such factors as pickling duration, diameter and depth of annular grooves, pre-heating, electrode and welding current, stress relief by post-heating, and mechanical stress relief:

Form of Testpiece :—

The most useful form of testpiece for sub-weld cracking was found to be similar to the Lehigh testpiece. In a test plate measuring 100 × 100 × 20 mm deep, an annular groove is cut (Fig. 5) and filled with weld deposit in one continuous run. In all the normal tests described, an electrode, similar to a heavily coated British Class 4 (B.S. 1719: 1951) electrode suitable for mild and medium-carbon steels was used. The quality of the weld as seen after pickling can be judged by a merit scale or by the average length of crack, if a more quantitative measure is required.

Duration of Pickling :—

When testpieces of this type, made from steels Nos. 2 and 4 in Table I, were boiled for 4 hr in the nitrate solution, the first cracks appeared, the length of which increased up to a boiling time of 128 hr (Fig. 6). Thereafter, no further increase in crack length could be observed, showing that crack formation had released all internal stresses. Consequently, it is considered that a pickling time of 200 hr can be expected to bring out all possible cracks and that any further increase in time would serve no useful purpose.

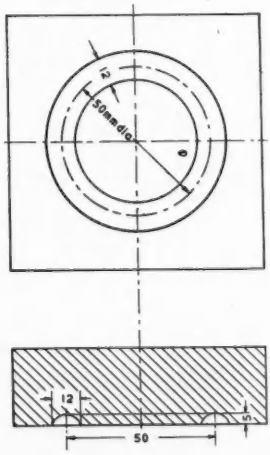


Fig. 5. Simple testpiece with an annular groove, for the determination of welding stresses.

Diameter and Depth of Annular Grooves :—

Tests carried out on steel No. 4 in Table I show that, if the diameter is so small that the weld forms virtually a full circular deposit, large cracks appear outside the weld material (Fig. 7a). The cracks noticed on testpieces with mean groove diameters between 40 and 60 mm do not vary significantly in length, but above 60 mm the conditions are again less favourable (Fig. 7b). An increased depth of groove gives rise to the formation of greater cracks, because the stresses increase with an increasing volume of weld material. These tests have proved the suitability of the testpiece shown in Fig. 5.

Pre-heating :—

It is at present believed that pre-heating decreases the danger of welding cracks, but it is not clear whether this is due to the reduced cooling rate giving a better grain or to a reduction in the welding stresses. A test series with the testpieces half immersed in solid CO_2, ice, water at room temperature, boiling water, or liquid tin showed no significant differences in the ensuing crack lengths (230 to 270 mm) on the welded surface after pickling. Consequently, any beneficial effect of pre-heating up to 250°C must be due to grain improvement. Pre-heating above 350°C affects residual stresses very erratically. After pickling, two testpieces were free from cracks, whereas another two testpieces showed crack lengths of 260 mm.

Electrodes and Welding Current :—

Bare and heavily coated welding electrodes of various steels and types of coating were used in a further series of tests on test-pieces of steel No. 1 in Table I. Oxy-acetylene welding, with its more distributed heat input and hence more even cooling, produced no shrinkage stresses in the relatively small testpieces used, whereas electric arc welding in every case caused such high shrinkage stresses that the cracks on the welded side surrounded the entire bead. With austenitic electrodes, however, the stresses did not reach far into the material.

Variations in electrode diameter (3·25 to 4 mm diameter in several runs, or 5 to 6 mm diameter in one run), as well as variations in welding current, i.e., maximum and minimum current values in each case, showed

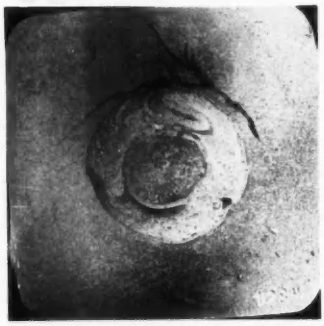
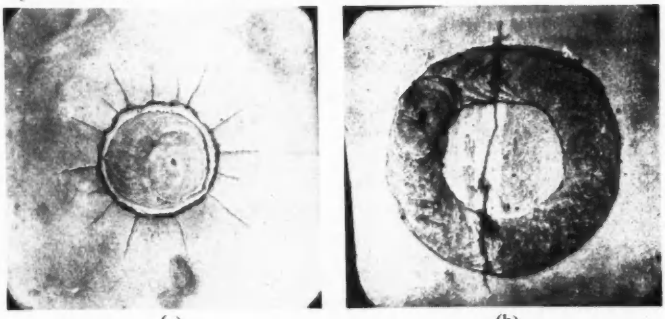


Fig. 6. **Crack formation in a steel plate after pickling for 128 hr.**

no differences in the lengths of cracks produced. Thus, even those welding methods supposed to generate low stresses still give rise to very appreciable internal stresses.

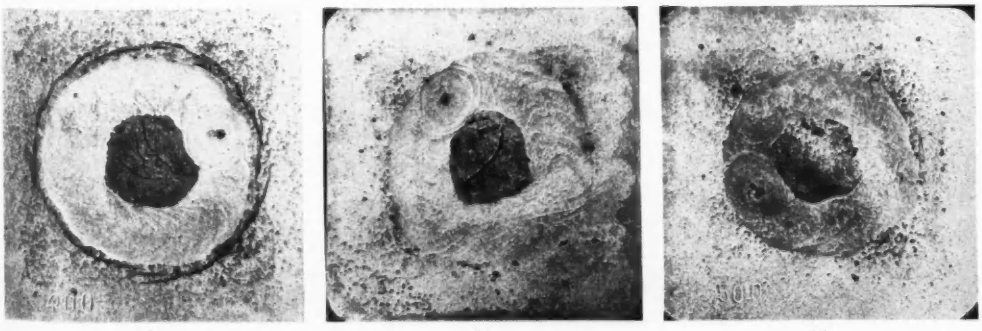
Stress Relief by Post-heating :—

Testpieces of steel No. 1 were welded with a heavily coated electrode, equivalent to the British Class 4 (B.S. 1719:1951) electrode, allowed to cool, then heated for 2 hr at various temperatures between 200° and 900°C, and finally pickled. Stress relief was first evident at 400°C (Fig. 8a), and at 450°C only small radial stresses remained in the vicinity of the terminal crater (Fig. 8b). After stress relief at 500°C, all effective stresses were eliminated (Fig. 8c). Similar tests with coated electrodes equivalent to the British Class 6 electrodes showed no fundamental differences.



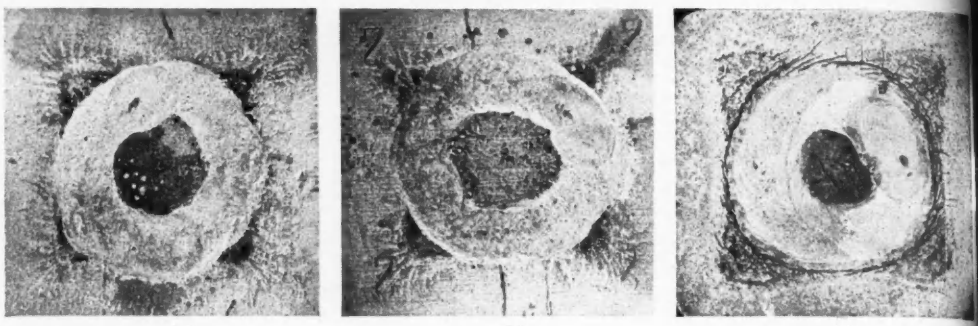
(a) (b)

Fig. 7. **Crack formation in a testpiece with (a) a small groove diameter, and (b) a groove diameter of more than 60 mm.**



(a) (b) (c)

Fig. 8. **Influence of stress-relief temperature on welding stresses after 2 hr at (a) 400°C, (b) 450°C, and (c) 500°C.**



(a) (b) (c)

Fig. 9. Influence of hammering on welding stresses, showing a testpiece (a) normally cooled in air, (b) hammered at red heat, and (c) hammered cold.

The admitted practical success of these electrodes cannot therefore be due to the supposed greater plasticity of the weld material during cooling, but must be due to other causes. Nevertheless, the results obtained cannot be generalized, as too little is known about the influence of various types of steels or even of melts. Thus, for instance, the higher-carbon steels seem to be more easily relieved, an appreciable reduction in stress being noted at a temperature of 300°C. A 42-ton steel proved even better than a 35-ton steel in this respect.

In a further test series, a mild steel was subjected to various heating times at temperatures between 400° and 500°C. The results showed that the duration of post-heating has much less influence than temperature, a period of only 15 min at 500°C being sufficient for complete stress relief, whereas appreciable stresses remained in the material after 16 hr at 450°C. That the results shown in Fig. 8 for steel No. 1 in Table I were more favourable than they were in this case is probably due to differences in the steels and in the manner of welding. In practice, it is usually believed that local heating of welds up to 600°C will eliminate welding stresses but, in fact, the pickling tests have shown that such a treatment often merely displaces the stresses, without actually eliminating them.

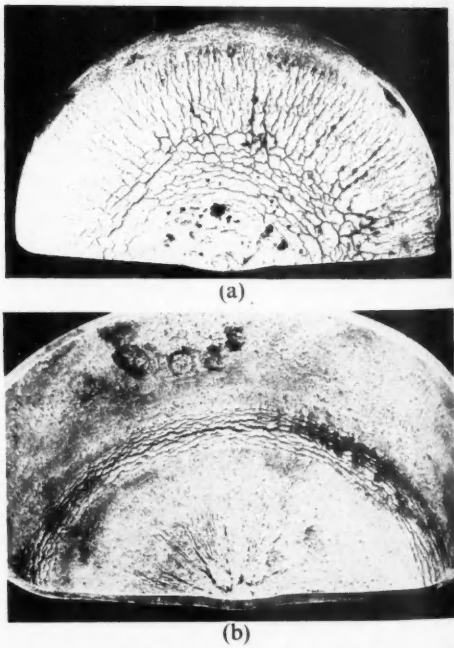
Mechanical Stress Relief :—

In a series of tests on steel No. 1 in Table I, one testpiece was cooled and then pickled normally, in a second testpiece the weld bead was hammered during cooling, while still red-hot, and in a third testpiece the bead was hammered after cooling. The pickled specimens (Fig. 9) showed that hammering not only eliminated radial shrinkage stresses around the weld but also introduced tangential tension, as evinced by the presence of isolated radial cracks, in this case caused by excessive hammering. Obviously, hammering of the still hot and plastic weld material had a greater effect than hammering of the cold weld, so that the radial cracks were more pronounced. Similarly, plastic deformation of the whole welded testpiece relieved stresses, a testpiece compressed just to first yielding between plates at right-angles to the welded face showing no cracks after pickling. Here again, as also quite generally, mechanical stress relief, if carried to excess, leads to the development of new internal stresses which may prove dangerous.

An attempt to relieve stress by drilling a concentric hole in the finished cold weld proved unsuccessful, the shrinkage stresses alone being insufficient for the cold deformation required for stress relief. Plastic enlargement of the hole may, however, prove to be more successful. Drilling the hole before welding, so that the entire testpiece could shrink, was also unsuccessful, as only the direction and not the magnitude of the stresses was altered.

Practical Applications

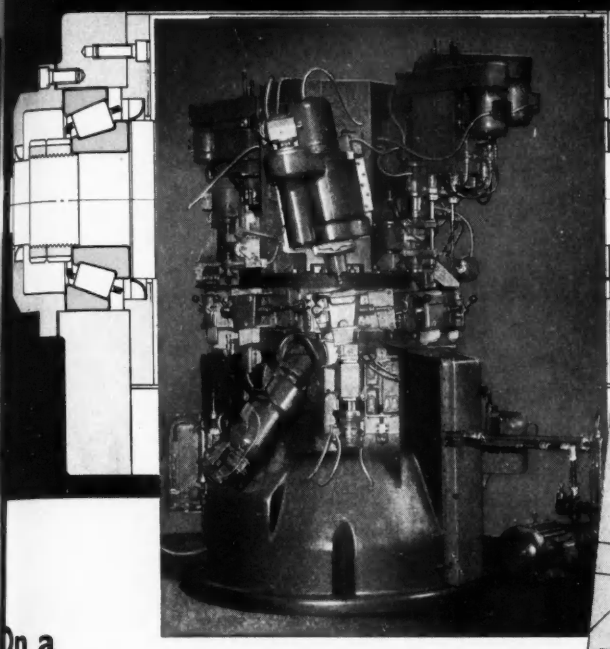
The method permits the detection of internal stresses in certain types of components or construction. For instance, Fig. 10 illustrates the stresses in the domed end of an oxygen cylinder of steel No. 5 in Table I, loaded up to about 100 atm. On the outer surface, the centre of the domed end is in residual compression ; surrounding it is an adjoining zone of radial tension and an outer zone of tangential tension. However, the most dangerous stresses are the meridional stresses noticeable on the inner surface at the transition between the domed end and the cylindrical portion of the cylinder.

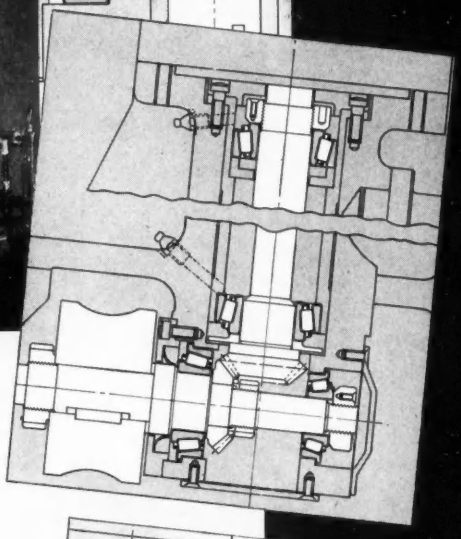


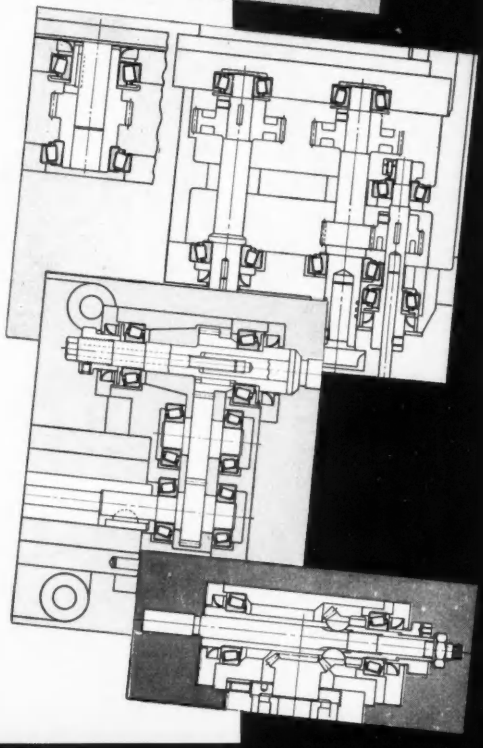
(a)

(b)

Fig. 10. Cracks caused by internal stresses in the domed end of a steel oxygen cylinder under a pressure of 100 atm, showing (a) the outer surface and (b) the inner surface.







On a rotary transfer machine for producing wooden rifle butts

This 8-station rotary transfer machine was designed and built by Boma Engineering (Bilston) Ltd. to mill and drill opposite sides of prepared wooden rifle-butt blanks. The machine accepts blanks of three different lengths, performs its 15 operations automatically and produces finished components at the rate of 1 per minute.

A rotating index ring carries eight air-operated fixtures for holding the workpieces, and after each indexing the ring is locked by a pair of hydraulically-operated plungers. The sequence of machining operations is controlled by a motor-driven drum cam, all motions being interlocked electrically.

Great attention has been paid to the bearing mountings in order to maintain 'rigidity' and alignment.

The line drawings show installations in which some of the 48 Timken bearings are employed, as follows:

1 Indexing mechanism
2 Milling head used for forming
3 Multi-drill and cutter head
4 Milling head, horizontal
5 Milling unit used for slotting

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TAPERED-ROLLER BEARINGS
MADE IN ENGLAND BY

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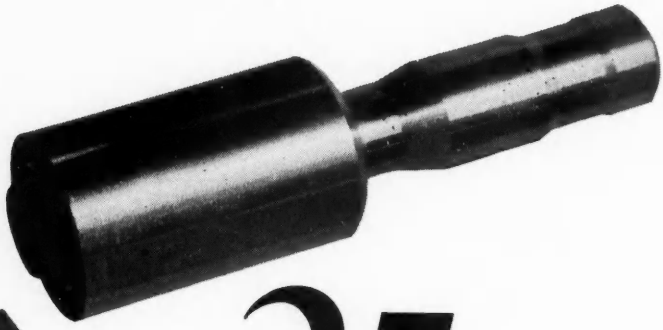

25 seconds

The machine time to remove 1 lb. 12 oz. of metal from a piece of bar to produce this gearbox inner column was exactly 25 seconds on a Churchill-Redman P.5 Lathe.

Another example of how the P.5 is cutting production costs.

Many outstanding features make such performances possible. For example, the massive overhead profiling carriage is hydraulically operated and designed specially to take heavy cuts at high feed rates—rates limited only by the rigidity of the workpiece and tool life.

The hydraulic feed is infinitely variable and can be automatically changed during cutting to obtain maximum performance.

★ *For the fullest details of the P.5 write to:*

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British Industrial Developments

Comprehensive Protection Equipment for Compressors

A system of comprehensive protection equipment which provides completely automatic supervision of all types of compressor has been developed by Teddington Industrial Equipment Ltd., of Sunbury-on-Thames, Middlesex, with the assistance of the National Coal Board and leading compressor manufacturers. The system, which can be applied equally well to reciprocating or rotary plant and which can be used for installations both above and below ground, provides advance warning of abnormal running conditions, followed by automatic shut-down before dangerous operation can occur. Not only does it prevent hazardous operating conditions, but it also protects the compressor against damage caused by accidents or lack of maintenance.

Basically, the equipment consists of a panel mounted on the compressor and (for underground use) a flameproof indicating unit, rotary switch, and alarm bell. The panel contains, in addition to the protection switches, all the usual temperature and pressure gauges, simplifying installation and bringing all the instrumentation for the

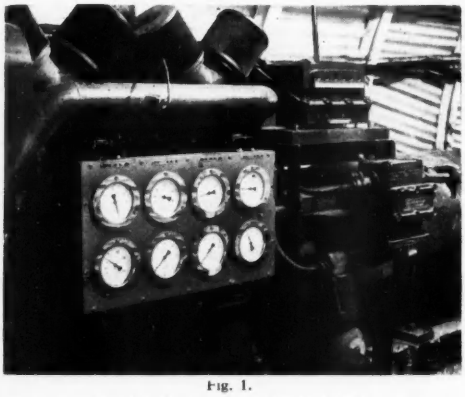

Fig. 1.

compressor together in one central unit. Such an arrangement obviously offers considerable economy, as compared with the fitting of a multiplicity of different types of instruments all over the machine. As an example of the instrumentation incorporated, a typical panel for a reciprocating compressor could include temperature warning and shut-down switches for the high-pressure and low-pressure discharge, an oil-pressure shut-down switch, low-pressure and high-pressure discharge- and inlet-temperature gauges, a pressure gauge for lubricating oil, interstage- and discharge-pressure gauges, and an oil-pressure gauge. In some cases, oil-temperature protection switches are also included and, in the case of water-cooled machines, the equipment incorporates water-flow protection. The panels can, in fact, contain virtually any combination of instruments required by the user. A typical panel is illustrated in Fig. 1. A novel feature is the method by which two instruments are coupled together on the same sensing system or pressure union. This again simplifies installation, since it reduces the number of insertion points on the compressor.

The motor-starter circuit is completed when the rotary switch is turned on, and, provided that normal oil pressure has been established within the 20 sec allowed by the time delay, it will be maintained thereafter through

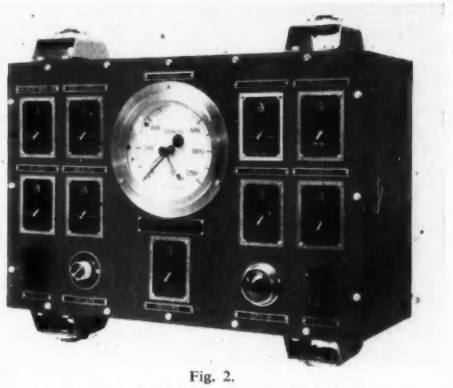

Fig. 2.

the protection switches in the panel and the shut-down relays. All the shut-down contacts of the relays are wired in series, to ensure that, when any one relay operates, the motor pilot circuit will be tripped. The compressor can be stopped manually by simply turning the rotary switch to the " off " position. The protection panel fails safe in the event of fault or damage, so that the compressor cannot run unprotected. If any damage occurs, or if any fault develops in the sensing systems, the protection switches will immediately break the circuit, and the warning or shut-down circuit will operate to call attention to the fault. For surface installations, the separate indicator unit is replaced by a series of latched fault indicators in the panel itself, as shown in Fig. 2. These indicators are interlocked, so that only the fault which causes the compressor to stop is indicated. Built-in audible and visual alarms are also fitted, when specified.

Sieving and Straining Machine

The latest addition to the range of equipment produced by Russell Constructions Limited, of London, W.C.2, is the " Invicta " sieving and straining machine. Powered by a 1½-hp motor and operating at 3000 rpm, this machine, which has a sieve diameter of only 3 ft, has an exceptionally high output in both dry-sieving and

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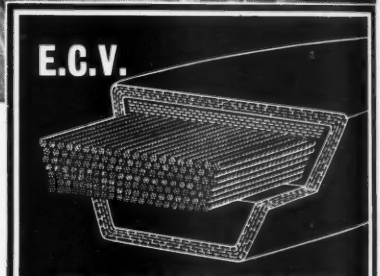
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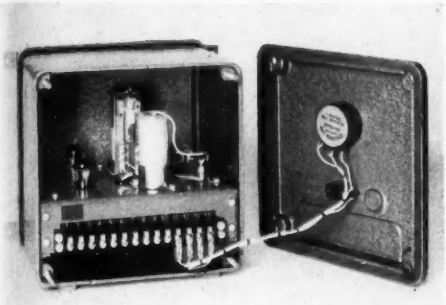
liquid-separation operations, so much so that it is capable of maximum outputs of over 12,000 gph of liquids, and about 10 tons per hour of powders. In operation, the machine is silent and gives excellent performance, even with very fine meshes, e.g., 300 per linear inch, while mesh-binding is practically impossible.

The machine utilizes the well-known vibrating gyratory principle used on other similar types of Russell machines, the vibrating unit being built into a rigid structure mounted on wheels for easier portability. The electric motor, of hermetic construction, forms part of the rigid frame and drives the vibrating generator via a flexible coupling. The sieving element is retained in the unit by quick-release clips, and is instantaneously detachable for exchange or cleaning, while the sieve can be completely stripped without the use of tools, and re-meshing takes only a few minutes and does not require any special skill.

Electronic Process-Timers

A new series of low-cost electronic process-timers has recently been added to the wide range of this type of equipment produced by Lancashire Dynamo Electronic Products Ltd., of Rugeley, Staffs. Designated series PCT.1, these timers are available in six basic forms, depending on the required time range, and can be connected together to provide multi-stage timing control for complete processes.

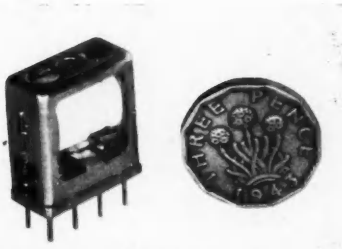


These six basic models are designed to provide time ranges of 0·1 to 1·5 sec, 0·3 to 5 sec, 1 to 15 sec, 3 to 50 sec, 10 to 150 sec, and 30 to 500 sec. Each main time range is subdivided into " long " and " short " ranges, selected by a switch, and a continuously variable control is provided for accurate setting of the required time interval. The units have a repeat accuracy of $\pm 1\%$ on a stable supply, and variations in supply voltage of -15% to $+10\%$ will not cause a change of more than $\pm 5\%$ in the set time interval.

The timers are housed in a robust cast light-alloy case designed for wall- or base-mounting and incorporating suitable sealing arrangements on the detachable covers for preventing the ingress of dust or moisture. The timing controls are mounted on the front of the case, the control for setting the time being provided with a scale calibrated directly in seconds.

Miniature Lightweight Relays

Filling the need for a miniature, lightweight, and robust relay of good sensitivity and fast operating times, the Clare " F " relay is now being manufactured in the U.K. by C. P. Clare Ltd., of London, N.W.10, a member of the Elliott-Automation Group, under licence from C. P. Clare & Co., of Chicago, Ill. This hermetically sealed relay (shown in the illustration with its cover removed) weighs only 0·52 oz, measures 0·85 × 0·8 × 0·396 in., and has been designed specially for printed circuits with a 0·1-in. grid. The terminals of the glass-to-



metal header are spaced 0·2 in. apart in two rows, also 0·2 in. apart. Solder-hook and 3-in. lead terminals are also available.

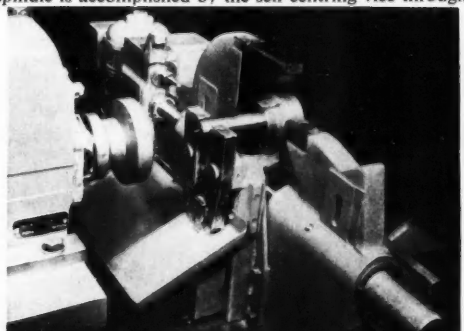
The relay, which has a rating of 3 A at 28 V d.c. or 115 V a.c., has a pick-up time of 3·5 milliseconds and a drop-out time of 1·5 milliseconds, the nominal operating power being 250 mW. Its temperature range is between $-65°$ and $+125°$C and, owing to its balanced armature construction, rigid frame, and high contact forces, it is capable of withstanding severe continuous vibration and a shock of 65*g* for 11 milliseconds.

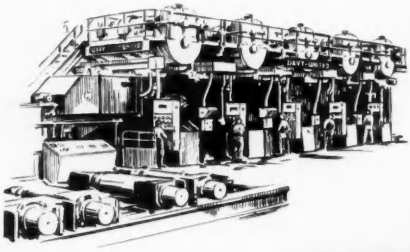
Initial production is being concentrated on the 26·5-V model, with a minimum operating current of 19 mA and a coil resistance of 675 ohms. However, other models, with voltage ranges between 6·3 and 110 V, will be introduced in the near future.

Modified Facing and Centring Machine

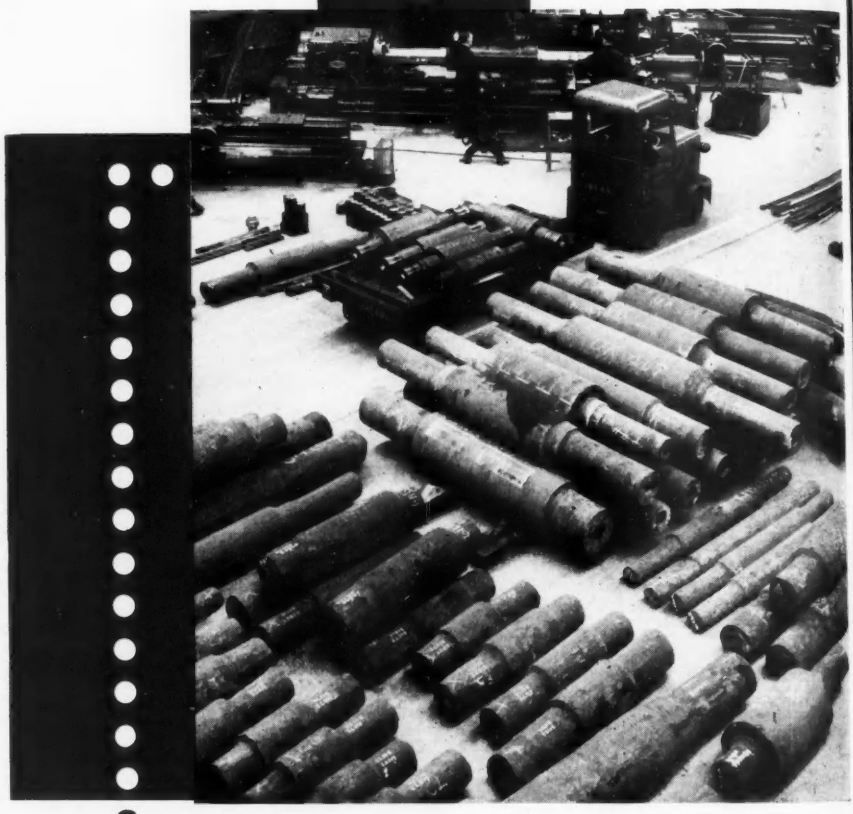
A special version of their " Endomatic " facing and centring machine, modified to accommodate the outer-race bell of a well-known universal coupling, has recently been supplied by Douglas Fraser & Sons Ltd., of Arbroath, Scotland. The machine is a single-ended SC2 model, comprising a heavy cast bed which carries the spot-facing and centring head, electrical control panel, and the slideways, on which is mounted a Fraser self-centring power-operated vice-unit. The spot-facing and centring head has a speed range of 314 to 1105 rpm through medium pick-off gears from a 3-hp motor, the spindle being carried in a hydraulically operated quill with a total travel of 3 in. The head carries a self-contained valve unit which provides any ratio of quill movement, from rapid approach to coarse and fine feed rate.

Clamping arrangements are designed for special-purpose application, since the component is located and clamped on two widely differing diameters. The difference in diameter between bell and stem is compensated by a cradle which ensures that the component is level and at a common centre height with the workspindle; the cradle also carries a dead-length stop for endwise location of the bell end. Transverse alignment with the work-spindle is accomplished by the self-centring vice through





The latest techniques in the rolling mill



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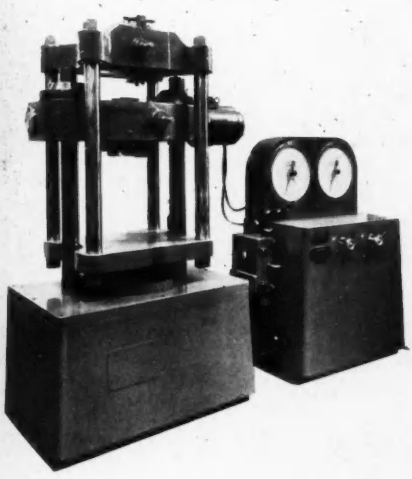
its electrically operated torque unit and differential lead screws, whilst the stem is clamped by a special compensating arrangement in which the clamping fingers are closed by the wedging action of a hydraulically actuated floating roller arranged to operate in sequence with the machine cycle.

The sequence of the automatic work cycle is as follows: The component is hand-loaded in the cradle and the bell end located against the end-stop. Depression of the starting button closes the self-centring vice, starts the spindle, and initiates the advance of the workhead. With the approach of the workhead the stem of the component is rigidly gripped by the compensating clamp. After facing and centring, the workhead withdraws and the clamp is automatically released; the " vice-open " control button is then depressed, and the workpiece is unloaded. This conversion is designed to produce 89 pieces per hour, working at 80% efficiency.

Hydraulic Testing Machines

It is announced by Edward G. Herbert, Ltd., of Levenshulme, Manchester 19, who manufacture Tinius Olsen hydraulic testing machines in the U.K. under licence, that these machines are now built in five capacities, i.e., 60,000 lb, 120,000 lb, 200,000 lb, 300,000 lb, and 400,000 lb. The first 400,000-lb machine built in Great Britain is shown in the illustration.



The machine is designed in such a way that the complete hydraulic and mechanical systems are enclosed in a welded frame constructed as a compact rugged unit. Tensile and compression tests are covered by standard equipment, comprising flat grips, Vee-grips, and a compression plate, but a complete range of accessory testing tools is also available, covering, for instance, transverse, shear, and bend tests.

Loads on the machine are indicated on two 16-in. diameter precision-type hydraulic gauges mounted on the instrument panel above the hydraulic and electrical controls. These gauges are provided with maximum pointers. The pressure actuating these gauges is developed in a ground and lapped piston and cylinder designed to operate without packings of any kind. A slight film of oil separates these surfaces at all times. With this design, friction is held to an absolute minimum, and the load is weighed to within close limits.

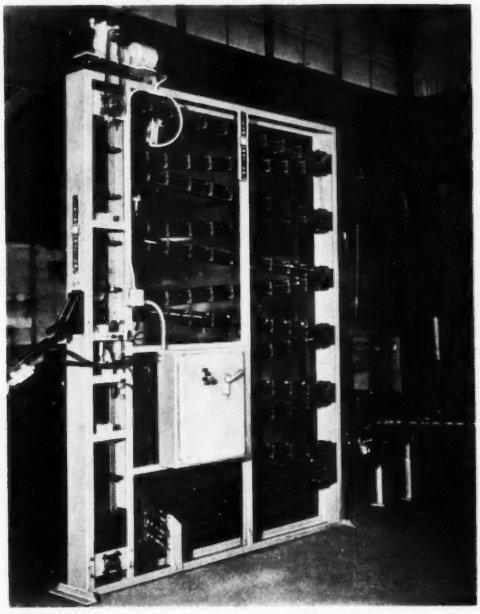
Load application is accomplished by a hydraulic piston and cylinder located in the base of the machine, so that the centre of gravity is extremely low. This feature eliminates the necessity for any rollers or guides and reduces the shock of breaking specimens. Load is applied to the specimen by motion of the piston, hydraulic pressure being developed from a direct-connected motor-driven gear-pump which, with an Olsen automatic valve, provides uniform rates of load application.

Normally, a range of testing speeds from 0 to 2 ipm is obtainable in stepless intervals, controlled by two pilot handwheels (load valve and unload valve) of 8 in. diameter. Because of this valve construction, loads may be easily applied, removed, or held constant. On the 60,000-lb machine, the middle crosshead is conveniently adjusted by means of a hand-crank in easy reach of the operator, but on all other machines the crosshead is adjusted by an electric motor.

Automatic Parts-Storing Units for Pipe Fittings

A high-capacity demand-feed storage unit for pipe fittings or any similar parts which can roll has been developed by the Gear-O-Mation Division of the Michigan Tool Company, Detroit, and is supplied by Gaston E. Marbaix Limited, of London, S.W.11. Designed for use in an automated processing line, the new unit will handle three different sizes of pipe fittings, though not at the same time, minor and easily made adjustments being necessary to change from one size of part to another. The equipment consists of " zig-zag " gravity part-retaining tracks, fed from integrated parts elevators, and has a maximum capacity of 1500 parts, depending on their size.

The unit features a by-pass track which permits direct passage of parts through the unit. Built-in five-digit counters (in the control panel) can be optionally supplied to provide a running parts inventory by tabulating " parts in " and " parts out ". Construction of the equipment is of the unitized type, using heavy-gauge steel welded into a combined frame and shell. All tracks and track elbows are made from wear-resistant die-stamped steel, and all controls are of the heavy-duty type. Normal service requirements are eased by conveniently located components and the use of " open " tracks.



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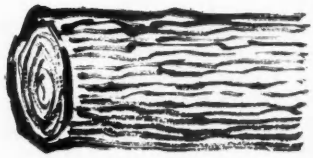

'Eclipse' hacksaw blades and other tools are made by James Neill & Co. (Sheffield) Ltd., and are obtainable from all tool distributors.

UH 27.

ADDITIONAL ABSTRACTS

Numerous important abstracts which, for lack of space, cannot be published in our main editorial columns are regularly included in condensed form in this section. Subscribers may obtain photostat copies of all original articles at cost.

Inherent Non-Linear Effects in Hydraulic Control Systems with Inertia Loading.

By J. K. ROYLE. (From a paper presented at a meeting of *The Institution of Mechanical Engineers, London*, January 16, 1959, 13 pages, 22 illustrations)

THE majority of hydraulic control systems, particularly remote position controllers, include a pilot valve in the control loop. The object of the valve in flow-control systems is to provide an oil flow proportional to pilot-valve displacement, which, in turn, imparts to a ram or B-end motor a velocity proportional to valve displacement. The ideal system assumes zero load on the ram or motor, and it is with this basic assumption that the linear dynamical performance of the system is calculated. In practical systems, the load on the ram or motor causes the pressures throughout the system to change, and the basic linear assumption is invalid.

In order to predict the design limitations and dynamical performance of a servo-mechanism containing in the loop a valve and ram or motor under load, it is necessary to relate the result of simple, idealized linear theory to that of the more involved non-linear theory which fully describes the practical performance of the ram. The theoretical results must then be compared with the experimental evidence, so that the combined investigation may lead to a better understanding of the non-linear nature of the problem.

This paper considers the inherent non-linear effects of inertia load on the performance of a pilot-valve and ram system. Such a system may be considered as a model for many valve-and-ram or valve-and-motor combinations found in hydraulic control systems, and the results are therefore expressed in generalized form. It is shown that cavitation can occur dynamically when linear analysis would predict that only $1/\sqrt{2}$ of the static stalled effort is being utilized. Prior to cavitation there is surprisingly little distortion and attenuation of the velocity wave-form of the ram when the valve is moved sinusoidally. The beneficial effects of exhaust lap are discussed, and the analysis is developed and qualified for the introduction of compressibility, friction, leakage, symmetrical lap, and dither. Experimental results are compared with the theoretical predictions, and the paper includes a note on the validity of small perturbation theory for this type of problem.

Hot-Upsetting and Tube-Redrawing Processes for Producing Complex Parts.

(From *Steel, U.S.A.*, Vol. 143, No. 25, December 22, 1958, pp. 64–66, 6 illustrations)

Two proprietary processes, known respectively as " metal-gathering " and " flotrusion ", are stated to make it possible to produce complex parts which it would be economically impracticable to produce by other methods.

Metal-gathering is basically a process for increasing tube-wall thickness or for building up the cross-section of a solid bar in localized areas. The end of the part blank is heated to forging temperature, and constant pressure (applied by a ram) forces the heated area to swell, gathering it into an integral heavy mass. In most cases, a forging operation shapes the mass to the desired configuration and is normally performed immediately after gathering, while the mass is still at working temperature.

Metal-gathering may be said to be an extension of metal-upsetting, in which there is a limit to the amount the rod diameter or tube-wall thickness can be expanded without producing folds or laps. In metal-gathering, the rod or tube is progressively gathered into the mass. In general, any metal that is forgeable can be metal-gathered, and, although the process has certain limitations, it also has several advantages. Thus, end-fittings can be made integral with the rod or tube, no weldments or mechanical attachments being required, while heat treatment is facilitated, since the whole part is made of the parent material. In addition, a minimum of machining is required on the formed ends, and in many cases no machining is needed on the centre-section of a tube to reduce wall thickness. Also, as the grain flow of the metal follows the contour of the gathered mass, the result is often increased strength and fatigue resistance.

Flotrusion is a precision tube-redrawing operation. With the aid of special tooling, heavy-wall tubing is drawn cold, to produce variable-wall parts. Contours on a mandrel can be reproduced in the tube, and multiple-tooling set-ups can produce a variety of outside and inside configurations on the same part. Heavy and light walls can be varied considerably in length and thickness, and either the outside diameter or the inside diameter can be held constant or varied, as required.

Balancing of High-Speed Four-Stroke Engines.

By R. CLINK. (From a paper presented at a meeting of the Automobile Division of *The Institution of Mechanical Engineers, London*, December 9, 1958, 18 pages, 38 illustrations)

THE problem of balancing the rotating and reciprocating components of high-speed engines has engaged the attention of engineers for many years, with the result that considerable literature is now available on this subject. Generally, the need to minimize external and internal force and couple unbalance is well recognized, since only in this way is it possible to avoid excessive vibration of the engine and its surroundings, as well as undesirable fluctuating loads on the engine and its mounting structure. Furthermore, an engine which is dynamically " quiet " is generally more silent and durable than one which is not.

Unbalanced rotating forces may be readily dealt with by the addition of counterweights to the crankshaft, although extravagant use of these is to be avoided. Not only do they increase engine weight and cost, but the additional rotational inertia which they produce may lead to difficulties in dealing with the problem of torsional vibration. It is pointed out in this paper that, where such weights are a necessity from the balance aspect, they may be designed as pendulum vibration absorbers, producing an engine which is smoother in a torsional sense.

Unbalanced inertia forces are normally dealt with by selecting an engine assembly which provides collective balance of the forces at the individual cylinders, and, in presenting this paper, the author considers that one of the best methods of studying these effects is by means of reverse rotation vectors. This method enables a clear picture to be obtained of the resultant unbalance effect of different engine arrangements and provides a ready means of determining the best solution. The representation of reciprocating forces by means of reverse rotation vectors is not new and, indeed, was the basis of the Lanchester second-order balancer for four-cylinder in-line engines.

Some of the engine-balancing arrangements in current use in the automobile industry are reviewed and discussed, and mention is also made of some of the more important practical problems encountered when carrying out actual

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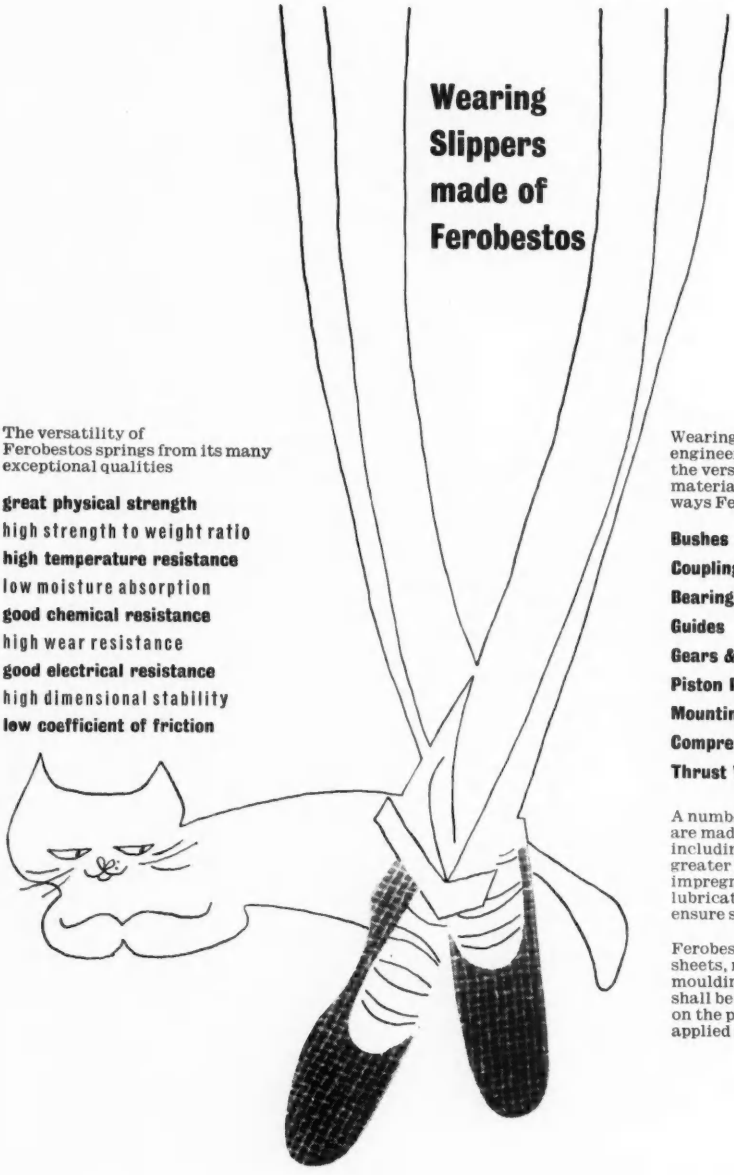

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balancing operations on crankshafts and their associated components. Variations in the balance of identical engines may be traced to assembly tolerances, and hence there is an increase in the practice of assembly balancing. As a logical conclusion, it is to be expected that final balancing operations will eventually be made on the complete engine on the test-bed.

A Simplified Approach to Calculating Design Stresses.
By O. W. BLODGETT. (From *The Welding Journal, U.S.A.*, Vol. 37, No. 12, December 1958, pp. 1182–1192, 23 illustrations)

THIS paper presents new and simplified design methods for creating efficient machine weldments. To speed this work by reducing the amount of time and effort to a minimum, the standard design formulae applied to designing a weldment have been made into nomographs, charts, and tables for quick, accurate use, and the more important techniques that have been developed are summarized.

At one time, the easiest approach to designing for welding appeared to be that of designing empirically from past experience. This is easy, but, unfortunately, a rule-of-thumb selection of configuration and section almost invariably results in machine members which are actually too heavy, giving rise to higher material costs, higher fabricating costs, and more welding than is necessary. Fortunately, this approach is gradually being discarded and the trend now appears to be towards machine designs with a guaranteed maximum deflection based on calculations. New methods of determining forces and their effects allow designers to determine sections according to these calculations, where previously the actual load values were indeterminate.

This approach makes for more efficient designs and more efficient use of the excellent properties of steel. The methods presented in this paper help in this approach by simplifying complicated stress analysis and the complex, time-consuming design formulae which must be used.

Bearing Tests with a Machine Producing Impulsive Loading.
By A. E. RUSSELL. (From an advance copy of a paper received from *The Institution of Mechanical Engineers, London*, January 1959, 12 pages, 15 illustrations)

IN diesel engines especially, on account of the high gas pressures involved, the crankshaft bearings have to withstand substantial loads. The trend towards higher specific engine output makes it necessary to place the cylinders of an engine as closely together as possible. This imposes a limit on the space available for the accommodation of bearing length, since the cylinder centre distance has to accommodate the width of a main bearing, two crank-web thicknesses, and the large-end bearing. The use of shorter bearings results in an increase in bearing pressures; in addition, the widespread adoption of pressure-charging has made increased demands on the bearings.

There is much published information on bearings covering a period of many years, but comparatively little has been reported on bearings subjected to the impulsive type of loading produced by compression-ignition engines. It was therefore considered that an investigation of bearings similar to those used in practice and subjected to this type of loading should be made, in order to examine the present limitations and, if possible, to seek means of improving performance.

As described in this paper, a machine for testing bearings under conditions of impulsive loading has been developed. The use of such a machine obviates the disadvantages that an engine entails in respect of accurate measurement of the actual load on the test bearing, replacement of damaged journals, facility for changing journal materials, and ease of examination of bearings. The machine also allows the bearing to be assessed on its own merit by freeing the bearing from the influence of deleterious factors introduced when a bearing is housed in an engine, e.g., indeterminate and variable mis alignment and contaminated oil.

In this paper, descriptions of the development of the prototype machine and the machine in its final form are given. The procedure for assessing the load capacity of bearings is described, together with the relative load-carrying capacities of various kinds of bearing material. The effects of changes in the lubrication conditions and also the effects of a certain amount of misalignment have been determined, while the changes in the running surface with increasing load and the effects of increased speed and of rate of loading (applied separately) have also been examined.

Kinetics of Hydrogen Absorption, Desorption, and Permeation with respect to Metals.
By T. G. OWE BERG. (From *Corrosion, U.S.A.*, Vol. 14, No. 12, December 1958, pp. 34–38)

THE reaction mechanisms for the absorption of hydrogen by metals from moist hydrogen gas and dilute acid solutions, for the desorption from metals of dissolved hydrogen in the presence of water, and for hydrogen solubility and permeation under these conditions are discussed in this paper, together with their kinetics. In addition, formulae are derived for rates and equilibria, and are compared with experimental data.

It is shown in this paper that desorption is accelerated by water. Thus, steel gives off its hydrogen much more rapidly when immersed in water than when held in air. Hydrogen is more rapidly absorbed from moist than from dry H_2 gas. Similarly, absorption from acid solutions is accelerated by As_2O_3, $HgCl_2$, and other additions to the solution.

Additions to the source of hydrogen cannot be expected to affect the rate of diffusion of H in the interior of the metal. They can affect only the surface processes by which H atoms are supplied to, or removed from, the surface of the metal. Consequently, under ordinary experimental conditions, particularly in the absence of such catalysts, these surface processes are slow. It therefore follows that, under ordinary experimental conditions, and especially under the conditions considered in this paper, diffusion in the metal is rapid, compared with the surface processes. The distribution of H in the metal during absorption and desorption can be assumed to be almost uniform up to at least 1-in. thickness.

Furthermore, comparing the formulae derived for absorption, solubility, and permeation with observations, agreement is reached as to the dependence on H_2 gas pressure, time, thickness of the specimen, and temperature. In particular, the observed activation energies agree, within the experimental accuracy, with those calculated. Within the experimental accuracy, the migration of H in the metal is associated with zero activation energy.

Vibrations of Pretwisted Cantilever Blading.
By W. CARNEGIE. (From an advance copy of a paper received from *The Institution of Mechanical Engineers, London*, January 1959, 22 pages, 17 illustrations)

THE comparatively recent development of the gas turbine has necessitated the use of pretwisted blading in the turbo-compressor and the turbine unit, and the pretwist imposed on the blades can be considerable, when flow calculations are based on the " free-vortex " theory. Accurate prediction of the frequencies of pretwisted cantilever blade vibration is of considerable importance, and this paper reports a study of the vibrations of such blad ng pretwisted linearly about the centroid of its cross-section up to an angle of $\pi/2$ rad. and considered to be encastré at the root.

Two theoretical approaches to the problem are discussed, the first of which, involving a direct solution of the equations of motion, is not used, although the characteristic equations are derived in an appendix for reference. The second approach is based on the application

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of Rayleigh's principle. For blades of uniform rectangular cross-section, frequency equations are derived for the fundamental mode of lateral motion and all the modes of torsional motion. Similar types of equation are shown to apply to aerofoil cross-section blading, since direct coupling effects between bending and torsion, being extremely small, can be neglected.

Vibration tests have been conducted on sets of blades of both uniform rectangular and uniform aerofoil cross-section, pretwisted between 0 and $\pi/2$ rad., the objects being to determine the frequencies and corresponding nodal patterns contained within a specified frequency band. The effect of pretwist on the measured frequencies of the lateral, torsional, and (for the aerofoil cross-section) coupled modes of vibration is shown, with certain exceptions, to be considerable. For the modes of motion where a theoretical solution is provided, reasonable agreement is shown to exist between the calculated and corresponding measured frequencies. Hence, the use of Rayleigh's method is justified, giving, as it does, relatively simple expressions for the natural frequencies of vibration.

The torsional frequencies of pretwisted blades are dependent on the torsional stiffness values. Consequently, a theoretical study of torsional stiffness variation with pretwist is presented, the results obtained being confirmed experimentally by means of a series of simple torsion tests.

Fatigue Tester for High-Temperature, Vacuum, and Controlled Environments.

By G. J. DANEK, JR., and M. R. ACHTER. (From *ASTM Bulletin, U.S.A.*, No. 234, December 1958, pp. 48–52, 9 illustrations)

As described in this paper, equipment has been developed for reverse bending fatigue at elevated temperature in a vacuum, using large strain amplitudes at low frequencies to produce failures in approximately 10^5 cycles. A major problem in the design of such equipment, i.e., the transmission of motion through a vacuum seal, was solved by the use of a magnetic coupling driven at the resonant frequency of the specimen. Two methods of vibrating the specimen were developed, one of which uses two oscillating permanent magnets outside the vacuum chamber, and the other two electromagnets excited alternately. Provision has also been made for automatically stopping the test when a crack has developed.

Fatigue data are presented for type-316 stainless steel in a vacuum of 3×10^{-5} mm Hg through a range of stresses at 1500°F. The results obtained show no more scatter than is generally experienced in fatigue testing. Even though two different driving mechanisms are used, the resulting data are comparable and indicate no great difference in deformation characteristics. However, since it has been found that the vibration can be controlled more accurately and conveniently by means of the electromagnets, and as a servo-mechanism can be added readily to electronic equipment, it is considered that the electromagnetic drive is better suited for life tests.

In vacuum fatigue, no appreciable oxidation takes place; consequently, in addition to environmental studies, this equipment may be used for metallographic investigations of fatigue damage and crack initiation and growth at elevated temperatures.

Control Amplifier with Saturable-Current Transformer and Switching Transistor.

By R. E. MORGAN. (From *Communication and Electronics* (*A.I.E.E.*), *U.S.A.*, No. 39, November 1958, pp. 557–562, 15 illustrations)

MANY control systems require reliable, fast-responding, compact, and economic amplifiers. Saturable magnetic circuits, combined with switching transistors, promise a satisfactory solution to these control requirements.

This paper describes a magnetic-transistor amplifier using a saturable-current 1-W transformer and a switching transistor dissipating 2 W, proportionally controlling a 300-W load. The saturable transformer-transistor circuit is an oscillator, the frequency of which is controlled by a direct-current winding of the saturable transformer. Details are also given of the methods of controlling the magnetic-transistor amplifier by a direct current and a variable resistor, and by a small integral magnetic amplifier which receives its power from the saturable-current transformer-transistor oscillator.

As a result of these investigations, it is concluded that the principle of using a combination oscillator and amplifier provides a reliable, compact, fast-responding, and economical control amplifier. Operating at frequencies between 1 and 10 kcs, it permits the use of compact components for controlling power. The power dissipated in the saturable-current transformer and the transistor used is approximately 1% of the load power capacity of the amplifier, providing a high-efficiency unit. The multi-stage amplifier using only one transistor provides advantages of compactness and fast response exceeding that of conventional magnetic amplifiers.

Three-Dimensional Flow in Axial Pumps and Fans.

By S. MIKHAIL. (From an advance copy of a paper received from *The Institution of Mechanical Engineers, London*, January 1959, 16 pages, 17 illustrations)

THE particular feature of a free-vortex design is that the circulation along each blade is constant and, since the flow in a free vortex is in equilibrium radially, the stream surfaces of the flow are concentric circular cylinders of the same radius before and after the rotor. When the blades are loaded in a manner which is different from the free-vortex type, radial components are induced in the region of the rotor and, in contrast to the two-dimensional nature of flow through free-vortex machines, the motion in non-free-vortex machines is essentially three-dimensional.

Marble has given a rigorous solution of the general problem of flow in three-dimensional machines, but has confined his treatment to the case in which the blade forces and their distribution are known. However, in the design of new machines, the distribution of blade loading could not be known, except after determining the effective free-stream flow pattern, in which the blades can be placed to supply the forces corresponding to the prescribed motions of fluid far upstream and far downstream of the rotor.

An attempt to solve this problem is made in this paper by replacing the rotor by a thin rotor disc of infinitesimal axial thickness, consisting of an infinite number of blades, and situated at the centre of gravity of blade loading. The problem therefore simplifies to one of finding the flow pattern which coincides with the flow motions at the upstream and downstream regions of the rotor and which gives continuous velocity components at the thin rotor disc.

In order to check the applicability of the developed theory, two series of rotors have been designed and tested in a special test-rig. Radial surveys have been carried out of total pressure, static pressure, and flow angles of fluid upstream and downstream of each test rotor. Special emphasis in testing the second series of machines (rotors and outlet guide-blades) has been made on the measurement of internal losses, in order to compare the efficiency of three-dimensional machines with the efficiency of free-vortex machines. Another object of this investigation was to determine the range and type of vortex flows that can be used and to establish their relative merits. In addition, the practical aspects of the possibility of using non-free-vortex flows in the design of axial machines have also been studied.

Despite the fact that these tests cannot be considered as conclusive regarding the value and distribution of losses, they serve to show that properly designed non-free-vortex machines can be as efficient as free-vortex machines.

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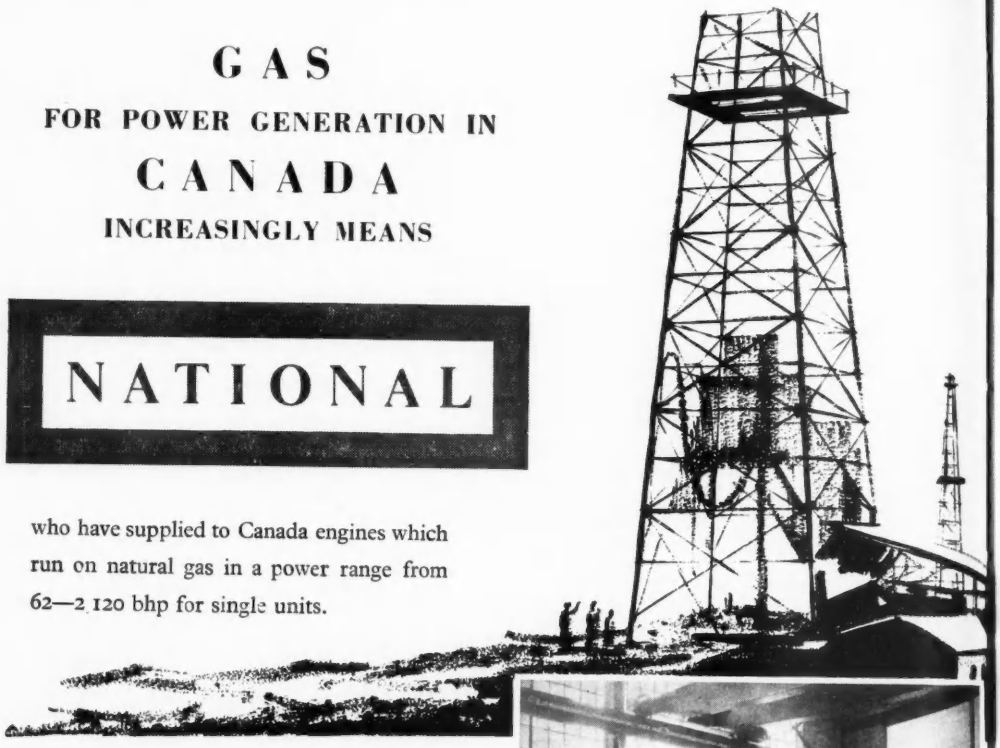

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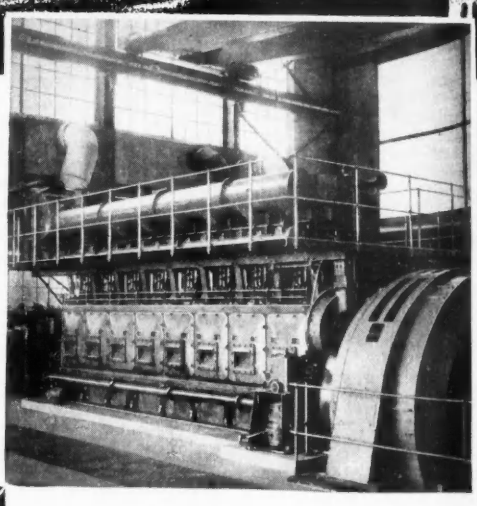

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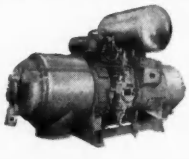

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New Materials, Processes, and Equipment

HIGH-SPEED MULTI-PURPOSE HYDRAULIC PRESS

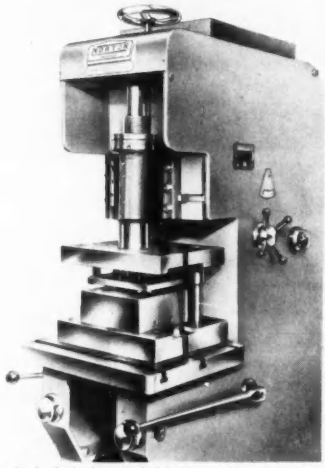
Designed for high production rates and speed in both operation and set-up, the new 7½-ton hydraulic press introduced by The Norton Tool Co. Ltd., of Smallfield, Surrey, is extremely versatile. Thus, it is eminently suitable for deep-drawing operations up to 2 in., for piercing and blanking, for compacting metal powders and ceramics, for assembly operations, and for forming and secondary operations. Furthermore, despite its compact dimensions (22 × 40 × 51 in. high), its physical capacities are high, making available an ample bed area (20 × 14 in.), daylight (14 in., or 16 in. without the table), and throat (8½ in.). Also, to facilitate maintenance, the machine is of unit construction and is entirely self-contained, no additional water supply for oil coolers or air supply for valve operation being required.

The main frame of the press is capable of withstanding tonnages and shock loads far in excess of the inherent capabilities of the machine. This high safety factor has the added advantage of providing a frame of exceptional rigidity, making the machine particularly suitable for precision production without the need for die-sets or expensive tooling. Two basic types of table, each easily detachable from the main frame, are available. One of these is a Tee-slot bed with a nesting centre adaptor ring reducing a round through-hole of 6 in. diameter to a through-hole of 2 in. diameter, while the other, also of Tee-slot design, has a 6 in. square centre hole with no reducing adaptor.

A notable feature of the press is the use of a specially designed multi-plunger high-pressure pump, giving a smooth and variable delivery in a series of 36 positive selections. The entire unit is of robust design and is capable of maintaining full pressure when working at a continuous rating of 7000 psi. The pump, which has a mechanical efficiency of 98·5% and a volumetric efficiency of 98·3%, is fully automatic and self-contained, and requires no additional priming devices, gears, or vanes. The machine is powered by a 7½-hp motor, driving via heavy-duty Vee-belts to the pump. The drive on the pump is a combined flywheel and Vee-pulley, and a considerable amount of power is available for use on blanking and similar operations from the flywheel itself. The high-speed flywheel, which operated at 1500 rpm, also carries the mounting for an induction fan, which supplies a continuous stream of cool air internally through the machine via an air-operated oil cooler. The warm air is finally ducted clear and to the back of the machine.

The hand control is of the ultra-sensitive type and has the effect of giving " feel " to the operator. As a result, a definite percentage of pressure on the handle will give the appropriate percentage of tonnage to the ram. This type of control is ideal for setting, assembly, etc., as it gives exceptionally fine control down to zero speed and movement, even when the machine is set for full speed. The semi-automatic control also provided is so designed that, at one depression of the handle, the ram makes only one full stroke and will not commence another stroke until the valve is depressed again. When the handle is depressed and held in the down position, the ram stays at the bottom of the stroke and will return only after the handle has been released. Both the hand-control and semi-automatic-control levers can be operated by a foot control, fitted on the pedestal or on a stand provided separately.

The characteristic control, of the star-wheel type, selects the desired requirements of the setter, in accordance with a chart on the machine, and covers hand-control only, semi-automatic cycling, fully automatic cycling, fully automatic cycling with repeat strokes at the bottom of the stroke, and fully automatic cycling with infinitely variable period of dwell at the top of the stroke. The actual ram exertion is indicated on a gauge immediately above this control, and at no time will the press exceed the pressure shown on this gauge.



Stroke is infinitely variable between $\frac{1}{32}$ and 6 in., and the machine is capable of about 600 strokes per minute on a ¾-in. stroke with automatic cycling. Pressing power is variable from about ¾ ton to the maximum of 7½ tons. Six standard pressing speeds, from 34 to 326 ipm, are available, and six standard fast-approach speeds, from 61 to 448 ipm, or any combination of these, making a total of thirty-six speeds, up to a maximum of 774 ipm down, or 686 ipm up.

HIGH-POWER TOGGLE UNITS

A series of toggle units, designed for core-pulling on die-casting and plastic moulds and for press-work applications on sheet-metal work requiring considerable power, has been introduced by the Engineering Tool & Product Co., Ltd., of Waltham Cross, Cheshunt, Herts. These units incorporate hydraulic or pneumatic cylinders which transfer their thrust to a ram through a toggle linkage, four sizes being at present available, i.e., with ram movements of 1, 1½, 2, and 3 in. respectively. Because of their toggle action, these units combine high pulling and thrust power with a positive mechanical lock when the ram is fully extended. This locking feature makes the units particularly suitable for use in applications where the ram is subjected to a high opposing force in the locked position, e.g., when holding cores in a die-casting mould.

The hydraulic or pneumatic cylinder is rigidly attached to a meehanite frame, the ram, in the form of a sliding block, being held captive in the centre of the frame by means of replaceable phosphor-bronze bushings at either side. Linear movement of the ram is obtained from pairs of toggle links pivoted at one end to the frame, and at the other end to the ram, which has a threaded hole or Tee-slots machined in its outer end, so as to allow attach-

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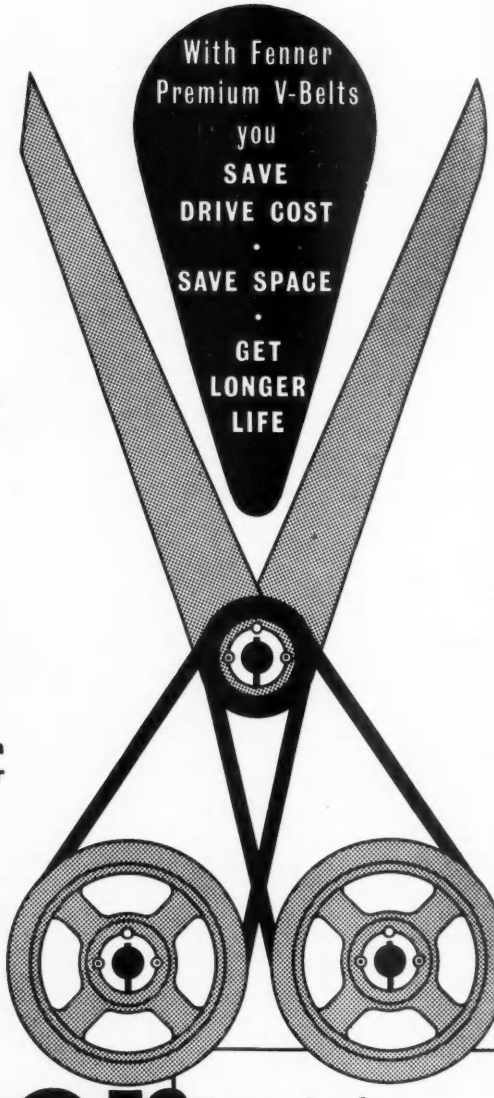

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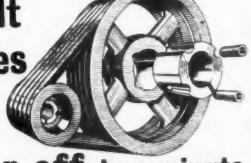

ON-or off-in a minute

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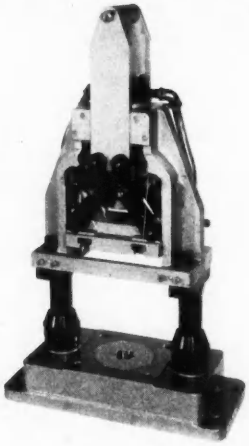
ments of any desired shape to be fixed to it. The method of machining and mounting the toggle links makes it possible for shoulders to be incorporated at each pivot joint. These shoulders are designed to relieve the pivot pins of any direct shear when the ram is subjected to a compressive load, as the shoulders formed by the links butt together when the ram is fully extended.



The frames of the units are designed with flanges, so that they can be rigidly bolted to any desired surface or mounting bracket. The 3-in. model illustrated is mounted on two pillars attached to a base frame, permitting it to be used as a bench press capable of exerting loads of 10 tons at approximately $\frac{1}{32}$ in. from the bottom of the stroke.

SURFACING PLATE FOR PRECISION GRINDING

When using magnetic chucks, there is always the possibility that the holding force can cause distortion by pulling down flat to the chuck surface an out-of-flat component which, on release, again becomes out of flat. Designed to overcome this problem, the " Lamalock " surfacing plate, introduced by A. A. Jones & Shipman Ltd., of Leicester, is an aid to precision surface grinding and is arranged to fit onto all types and sizes of permanent-magnet or electric surface plates.

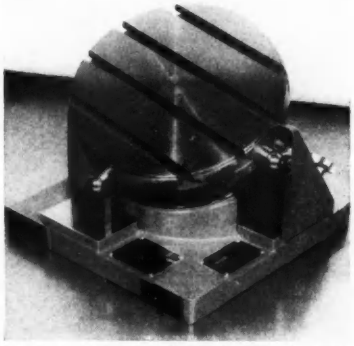
The function of the plate is to provide a multiplicity of automatic packings of extreme robustness, combined with sensitivity, accuracy, and ease of operation. This is achieved by incorporating a large number of small but powerful Lamalock plungers into a magnetic-chuck adaptor plate and producing it in such a way that it can be readily mounted on and dismounted from an existing magnetic chuck. In effect, the method locks hydraulically two or more relatively movable components, without the use of moving parts.

In this way, the Lamalock surfacing plate makes it possible to build into the plate a " mattress " of plungers with close-pitched centres, all capable of being locked simultaneously by means of a simple jack-screw piston, the operating procedure comprising loading the chuck, switching on and off, locking the plungers, switching on the magnetic field, and machining the component. The purpose of switching on and off the magnetic field is to ensure that the components will be pulled towards the chuck and hence depress the plungers, the residual magnetism after switching off being sufficient to hold the component to the chuck surface, but insufficient to cause it to be distorted flat onto the chuck. At this stage the plungers are locked, the component being machined in its unstressed state. When an accurate datum face has been machined, the plate is removed and the normal chuck surface is used for subsequent operations.

HIGH-PRECISION COMPOUND-ANGLE SINE TABLES

Considerably improved in design and appearance since the introduction of the original 9-in. diameter prototype, the new high-precision compound-angle sine tables announced by the Coventry Gauge & Tool Co. Ltd., of Coventry, are available in five models, with table diameters ranging from 9 in. to 36 in.

The outstanding feature of these tables is that the conventional hinged bearing at 90 deg. is replaced by a hemisphere riding in a spherical seating and permitting any angle up to 45 deg. to be set as a single or a compound angle. The work-table provided by the upper surface of the hemisphere is fitted with Tee-slots for clamping purposes. The advantages of this design lie in greatly increased rigidity and higher and more lasting accuracy (to within 10 sec of arc). In addition, the work-surface is always over the centre of the base, and no wear or slackness can develop, as in the case of the conventional hinged type.



The sine settings are obtainable by the insertion of slip- or block-gauges underneath two hardened precision spheres spaced exactly 90 deg. apart, the gauges resting on the appropriate hardened platforms on the base. One of the hardened spheres is located against the vertical face of a detachable straight-edge, to ensure that the first inclination of the table is in a plane parallel to the datum abutment face machined on the base, the second inclination for a compound angle automatically being in a plane at right-angles to the first setting.

As an example of setting procedure, to set the 9-in. table in a horizontal plane, a constant slip- or block-gauge value of 3·7500 in. is inserted underneath each sphere. To set a single angle α, a gauge combination to the value 3·7500 in. is placed underneath the sphere nearest to the datum abutment faces, and the value $3{\cdot}7500 - (5 \sin\alpha)$ is placed underneath the remaining sphere, care being taken to maintain contact between this sphere and the vertical face of the removable bracket. To compound the angle, the gauges are inserted for α, and, for the second angle β, a combination to the value of

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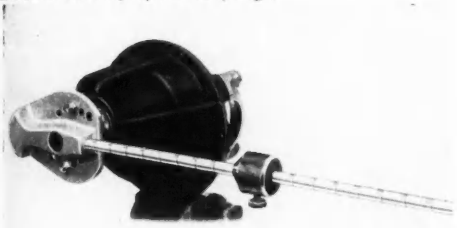
$\frac{3}{7500}$ — (5 cosα sinβ) is inserted underneath the sphere nearest to the datum abutment faces. When setting is completed, the gauges are removed and the table is locked by tightening the nut to secure the central bolt. The wedge action of the hemisphere in the seating assists this operation, so that only light pressure is required on the spanner.

PINION-BEARING PRELOADING GAUGE FOR AUTOMOBILES

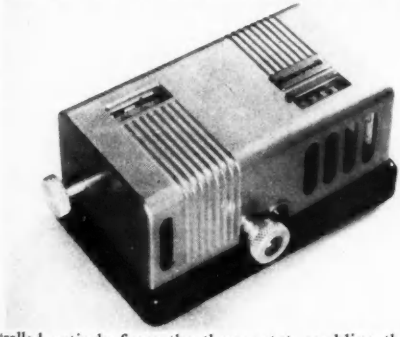
Designed to ensure correct preloading of the pinion bearing of automobiles, as is essential for quiet running and long life of both pinion and bearing, the pinion-bearing preloading gauge introduced by J. W. Pickavant & Co. Ltd., of Birmingham, can be used for all cars fitted with Hardy-Spicer couplings.



In operation, the tool is bolted to the pinion flange coupling, except in the case of the Ford 8- and 10-hp models, which utilize a torque-tube drive, where it is positioned on the splined pinion shaft. The tapered end of a slide weight is then adjusted to the appropriate position on a calibrated rod, corresponding to the reading on a comprehensive chart of preloaded torque values supplied with the instrument.

THERMOSTAT WITH THREE-POSITION MANUAL CONTROL

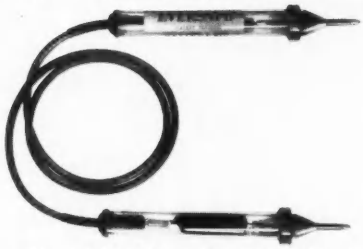
A new thermostat announced by Honeywell Controls Ltd., of Greenford, Middlesex, can be used to solve a ventilating problem in factories and other large areas using heaters and forced-air convectors for basic heating, inasmuch it utilizes an additional control to operate the fans in hot weather, when the heating plant itself is shut down. As a result, a unit heater installation can be controlled entirely from the thermostat, enabling the operator to run the equipment automatically, as with a conventional thermostat, or continuously, regardless of temperature factors. In addition, it permits the fans to be stopped completely, if required. The thermostat also provides a useful domestic service for loads up to 4 kW, the heavy loading allowing the installation of appliances which will heat a room much faster initially, without the added expense of installing a double-pole switch.



The basic feature of the new thermostat is the provision of a three-position manual control, fitted with a locking device to prevent it from being altered by unauthorized persons. The three positions are (1) " automatic ", which brings the conventional function of the thermostat into operation. (2) " on ", which allows the fans of unit heaters to operate, even when the thermostat does not call for heat, and (3) " off ", which shuts down the plant completely. This thermostat is available with or without a built-in thermometer, and is intended for use with low-voltage or line equipment, such as radiators, unit heaters, immersion heaters, cooling equipment, solenoid valves, contactors, and starters.

SHOCK-PROOF TEST-LAMP FOR ELECTRICIANS

Stated to be reliable and inherently safe at all times, a new electricians' test-lamp or potential indicator produced by Westool Limited, of St. Helen's Auckland, Co. Durham, is specifically intended to eliminate the danger of accidents occasioned by the use of faulty indicators of conventional design. For this purpose, the new design incorporates a high-value resistor in each of the two probes, so that, even in the event of insulation failure in the cable connecting the probes, current is limited to a value which cannot produce any shock hazard.



The unit, which is light and compact, is intended to operate on potentials from 250 to 650 V, does not use springs or screwed contacts, and is so designed that repairs cannot be made and broken units cannot be used, so that it remains safe throughout its working life. The indicator is a neon lamp, with wire tails taken out at the opposite end of the tube, giving a long leakage path. All components and connections are hermetically sealed in a thermosetting resin, which is non-tracking and is unaffected by heat and acids. This material is transparent, facilitating inspection of the unit at any time.

HIGH-SPEED TEST EQUIPMENT FOR TRANSISTORS

Stated to be the most advanced transistor test set in the world, the Winston Transistor Curve Tracer, manufactured by Winston Electronics, Ltd., of Shepperton, Middlesex, makes it possible to test a transistor for all its characteristics in less than one minute, as compared with the period of weeks required by conventional methods. The transistor is merely plugged in to the unit, and a number of dials furnish the complete data, with the characteristics displayed as curves on a cathode-ray tube. Complete data are obtained for both *p-n-p* and *n-p-n* transistors, because the characteristics for the grounded-base or the grounded-emitter condition can be displayed. Furthermore, with a view to catering for possible future developments in transistors, the voltage ranges provided are far greater than those required by the ratings of existing transistors. The current ranges cover transistors in medium power-output stages.

As the mean power dissipated in the transistor is usually only 25% of the peak high power, characteristic curves, which would otherwise be impossible to obtain with d.c. plotting, can be displayed. If required, permanent records of these curves can be made by using an oscilloscope camera over the cathode-ray tube. This tube has its own heater supplies and display amplifiers, and is the flat-face type, 6 in. in diameter, giving a green

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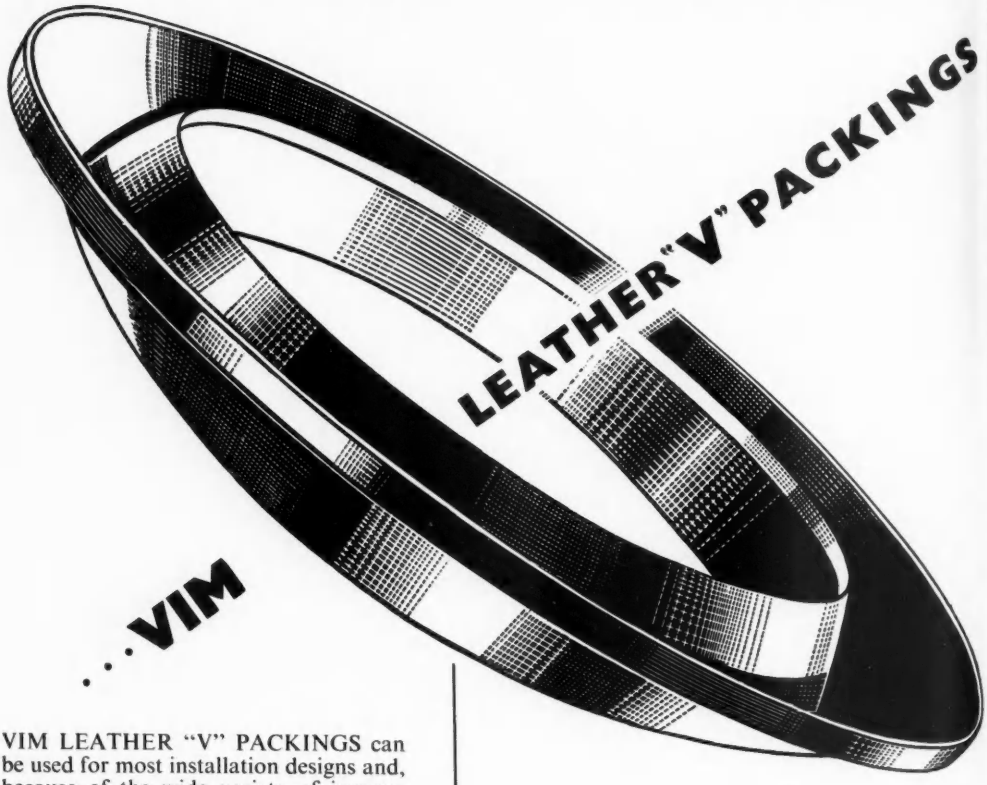

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Metal Cutting Oils, Drawing Compounds, Rust Preventives, Hydraulic Oils and Fluids, Special Lubricating Oils and Greases, Heat Treatment Oils and Salts, Industrial Cleaners, Fuel Oil Additives.

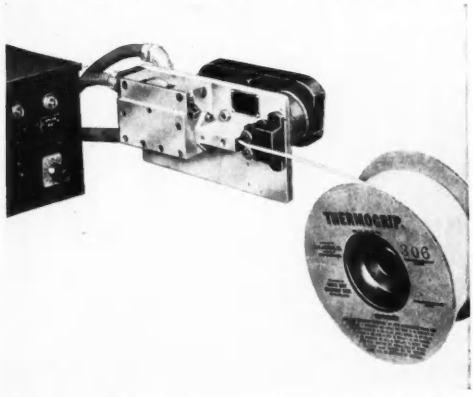
trace with medium persistence. A round Perspex measuring graticule of 1-cm squares is provided, and horizontal and vertical datum lines are co-incidentally engraved on both faces, so as to ensure freedom from parallax. Curve intensity is variable for both viewing and photography.

The instrument is housed in a cabinet measuring approximately 26 in. wide by 24 in. deep by 55 in. high, and is of unit construction, permitting simple and rapid withdrawal of units for servicing. All d.c. currents and voltages are displayed on six meters, which have 3½-in. mirror scales and are fitted with knife-edge pointers. Base voltages are metered via a valve voltmeter circuit which does not load the base circuit in any way.

All other meters are directly connected to the transistor electrodes. Great flexibility is obtained by the provision of a large variety of outputs applicable to any terminal of the transistor, in wide ranges of voltages and constant currents and in display switching. Full-screen deflection can be obtained from 0·6 V d.c. At least one transistor at a time is d.c.-coupled to the display system, thus ensuring a correct zero-level setting. The display can be calibrated at any time against a d.c. voltmeter. Flyback is suppressed at all times. Continuously variable voltages, pu to —150 V d.c., can be applied to the transistor collector and up to +150 V d.c. to the emitter, the maximum current in both cases being 60 mA.

HOT-MELT ADHESIVE APPLICATOR

A new type of hot-melt adhesive applicator designed to feed, melt, and apply a cord-like adhesive is produced by the United Shoe Machinery Corporation, of Boston, Mass. Designated the " Thermogrip " applicator, Model CW, the unit is supplied complete with electrical heat controls and is designed for incorporation into machines where glueing, spotting, or applying is required. A transfer-wheel method of applying the molten adhesive to individual passing objects is used, the wheel being specially designed to apply a desired pattern. A special feature of the device is that it functions equally well on its side or upside down, thus making the fast-setting hot-melt adhesive adaptable to a greater variety of uses. Typical applications include package ends, tabs, or sides, and non-package operations where a quick-setting automatic glue assembly is desired. The illustration shows (left to right) the control box for exact temperature adjustment, the " Thermogrip " applicator, and the reel of $\frac{3}{16}$-in. diameter adhesive.



During operation, the unit automatically feeds and melts from the reel adhesive. This principle of feeding, melting, and immediate application protects the adhesive from heat damage and makes possible the use of more effective formulations not practical with bulk melting pots. Daily clean-out of pots and adhesive-applying parts is eliminated, the hot melt being available a few minutes after turning on the current.

The Use of Semiconductors for Strain Gauges

(*Concluded from page 76*)

along the cylinder, are normally at neutral positions but, when a torque is applied to the free end of the cylinder, a voltage is generated across them. This voltage is directly proportional to the torque, and for this reason no balancing bridge is required. Besides its sensitivity, this transducer has the advantages that it responds to both steady-state and alternating torques, and that the angular displacement is negligible. Fig. 3 shows the voltage generated across electrodes (1) and (2) of this transducer as a function of torque for three different values of biasing current.

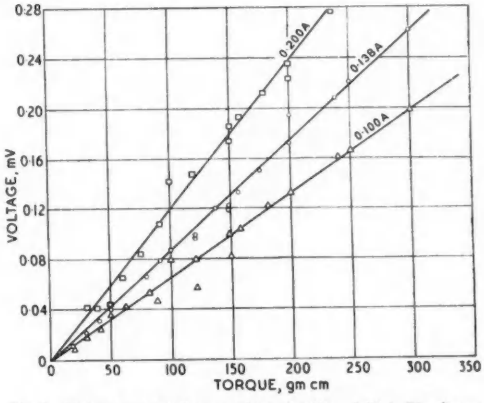
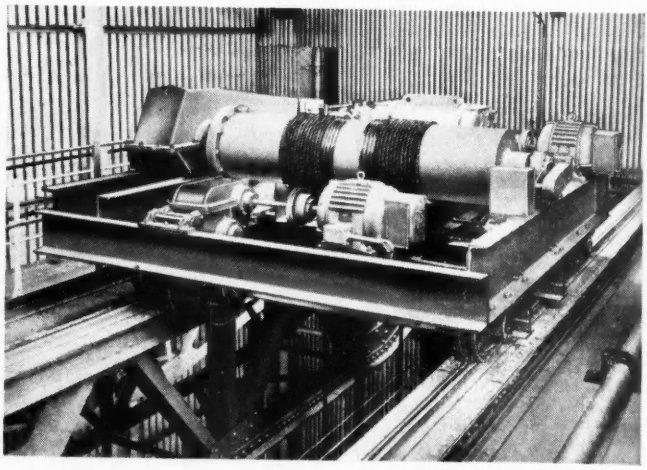


Fig. 3. Voltage generated across electrodes (1) and (2) in Fig. 2 as a function of torque for different values of biasing current.

In experimental work at the Bell Laboratories, crystals have been prepared and cut so that their unstrained resistance was 55 ohms, i.e., the same resistance as that of a common wire-type element. Thus, the same bridge circuit and other associated equipment can be used merely by substituting the new gauges. These advantages mean that semiconductors have nearly all the qualities needed for an ideal gauge. There are still extreme conditions for which no simple measurement device is adequate, but the new gauges offer such greatly expanded characteristics that research, development, and testing groups are sure to find many uses for them.

taking the strain



Under the stresses and strain of rough industrial handling, equipment needs to be strong, reliable and easy to handle.
Wharton cranes have been designed to thrive under such conditions and to perform all their tasks with easy precision.
Typical of Wharton cranes of medium capacity range, required for rigorous and continuous service, is this design which incorporates steel fabricated gear boxes and has ball-roller races throughout.
The crane illustrated was supplied to Messrs. Colvilles Limited, Motherwell, for installation at their Ravenscraig Works.

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SCOTLAND	Fisher-Baxter & Co., 140 West George Street, Glasgow C. 2.	Phone: Douglas 1061-2-3.	Grams: Fluorspar, Glasgow.
MIDLANDS	A. R. Holland & Son, 89 Cornwall Street, Birmingham 3.	Phone: Central 1457.	Grams: Central 1457, Birmingham.
SOUTH-WEST	R. C. Collins, 48 Westbourne Road, Penarth, Glamorgan.	Phone: Penarth 1527.	Grams: Penarth 1527.
NORTHERN COUNTIES	Fisher-Baxter & Co., 140 West George Street, Glasgow C. 2.	Phone: Douglas 1061-2-3.	Grams: Fluorspar, Glasgow.
NORTHERN IRELAND	General Engineering Products Ltd., 7/9 Great Patrick Street, Belfast.	Phone: Belfast 23743.	Grams: Belfast 23743.
EIRE or SOUTHERN IRELAND	Charles Nolan & Co., 2 Parker Hill, Lower Rathmines Road, Dublin.	Phone: Dublin 93510.	Grams: Dublin 93510.
CANADA	Marshall Equipment Co. Inc., P.O. Box 28, 61 Victoria Avenue, Dorval Station, P.Q.	Phone: Melrose 1-3528.	Grams: Marquipco, Montreal.

REPRESENTED IN PRINCIPAL COUNTRIES THROUGHOUT THE WORLD.

NEWS OF THE MONTH

PERSONAL

The Council of Industrial Design announces that **Sir Gordon Russell, C.B.E., M.C., R.D.I., F.S.I.A.,** has decided to retire from the directorship of the council on December 31, 1959, when he will be sixty-seven years of age. He will be succeeded by **Mr. Paul Reilly,** who joined the staff in 1948 and has been deputy director since 1954.

The Metropolitan-Vickers Electrical Co. Ltd. announce the appointment of **Mr. H. West, Assoc.M.C.T., Hon.M.Sc.(Manchester), M.I.Mech.E., M.I.E.E., Member A.M.E.M.E.,** as assistant managing director.

Mr. H. C. Elsden has been appointed managing director of Ross Courtney & Company Ltd., in succession to **Mr. J. W. C. Milligan,** who remains on the board. Mr. Milligan is managing director of the parent company, the Southern Areas Electric Corporation Ltd.

Sir William Scott, O.B.E., M.I.Mech.E., M.I.P.E., J.P., managing director of Armstrong Whitworth (Metal Industries) Ltd. and **Sir Richard Bellingham Graham, Bt., O.B.E., J.P.,** have been appointed directors of Head Wrightson Teesdale Ltd.

BTR Industries Ltd. announce that they have appointed **Mr. J. K. Davies** as assistant secretary, **Mr. E. N. Lowe** as general overseas manager, **Mr. Ian Keith** as general manager of the Hose Division, **Mr. C. K. W. Lewis** as home marketing manager, and **Mr. J. S. Exley** as special assignments manager of the Belting Division.

Mr. Arnold Carr, deputy chairman of Thos. W. Ward Ltd., has been appointed chairman of three subsidiary companies, Thomas Smith & Sons (Rodley) Ltd., John Smith (Keighley) Ltd., and Widnes Foundry & Engineering Co. Ltd., following the death of **Mr. Frank R. Stagg, M.I.Struct.E.,** who was for many years chairman of these companies.

Mr. J. A. Hayward has been appointed to the board of Firth Cleveland Limited.

Mr. D. D. Morrell, managing director of The Mitchell Construction Co. Ltd., has been appointed a director of Mitchell Engineering Ltd.

Holman Brothers Ltd. announce the appointment of **Mr. J. M. Williams,** director of the company's two subsidiaries, Climax Rock Drill & Engineering Ltd. and Maxam Power Ltd., as associate director of the parent company.

Mr. D. A. Wooley has been appointed manager of the London office of Allis-Chalmers Great Britain Ltd. He replaces **Mr. D. C. Altman,** who has been appointed assistant managing director of the company.

Mr. N. F. T. Saunders, B.Sc., M.I.E.E., has been appointed managing director of Kelvinator Limited.

Lancashire Dynamo Holdings Limited have appointed **Mr. D. C. Lorkin, F.C.I.S.,** managing director, and **Mr. R. A. Bent, A.M.I.E.E., A.M.Brit.I.R.E.,** a director of the company.

It is announced that **Mr. W. E. A. Redfearn,** deputy managing director of English Steel Forge and Engineering Corporation Ltd. and a director of English Steel Rolling Mills Corporation Ltd., has been appointed a director of the English Steel Corporation Ltd.

Mr. A. McVie, B.Sc., A.C.G.I., has been appointed general manager (overseas), and **Mr. A. G. Slemeck, B.A. (Oxon)** general commercial manager, of Standard Telephones & Cables Ltd.

The English Electric Co. Ltd. announce that they have appointed **Mr. E. B. Banks, A.M.I.E.E.,** director of commercial policy, contracts and sales, **Mr. P. L. de Laszlo, O.B.E.,** director of corporate affairs, **Mr. W. M. Hurton,** director of group manufacturing development, and **Mr. L. H. Short, M.C., M.I.E.E., M.Inst.T.,** director of overseas operations.

Mr. D. G. Ashton Davies has been appointed sales manager of the Instrument Division and **Mr. Charles Kramskoy** chief engineer of the Commercial Division of E.M.I. Electronics Ltd.

Fluidrive Engineering Co. Ltd. announce that, in connection with the expansion of their engineering sales department under **Mr. W. H. K. James,** they have appointed **Mr. J. W. Lee** as sales manager, **Mr. A. W. R. Willis** as chief application engineer (motors), and **Mr. R. V. Adams** as chief application engineer (engines).

Mr. Steven P. J. Wood, president of the Warner Electric Brake and Clutch Company, of Beloit, Wisconsin, U.S.A., has joined the board of Westool Limited, who manufacture Warner electromagnetic clutches and brakes under licence in this country.

Mr. R. Fulton has been appointed marine manager of Air Control Installations Ltd., of Ruislip, Middx.

Mr. Cecil Dotson of Dallas, Texas, U.S.A., has been appointed chairman of Texas Instruments Limited, of Badford, manufacturers of silicon semiconductors.

CHAPMAN & HALL

★ *New Books* ★

MATHEMATICS APPLIED TO ELECTRICAL ENGINEERING

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A. G. WARREN

SECOND EDITION—REVISED

480 pages *Illustrated* *70s. net.*

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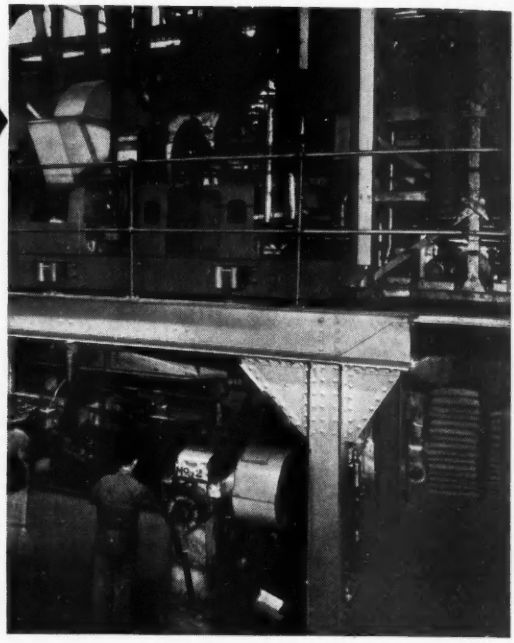
did this for us



What can they do for you?

Here on an upper floor, is an Internal Mixer—some 16 tons of machinery that, in producing rubber mixtures for high quality industrial products, transmits a ceaseless stream of vibrations to the floor and foundations. Few foundations could withstand such shocks without special reinforcement—much less upper floors. But mounting the Mixer on BTR Vibro-Insulators has enabled BTR works engineers to site it on an elevated platform which, as the photograph shows, is not unduly thick. The Vibro-Insulators absorb the shocks so effectively that the operator on the mill below can be quite unaware that the Mixer is even working.

If you have machinery whose vibration is possibly damaging foundations or building structures or impairing health and efficiency with excessive noise, ask BTR engineers about the advantages of mounting on BTR Vibro-Insulators.

BTR Industries Ltd

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TELEPHONE: VICTORIA 3848

BTR

ENGINEERS IN RUBBER

2/2672.

C. M. W. Thomas, A.M.I.E.E., has been appointed a director and **Mr. A. C. Risbridger, A.M.I.Mech.E.,** general manager of Klaxon Ltd., a member of the Windsor group of companies.

Following the retirement of their managing director, **Mr. R. E. Wilson,** Fescol Ltd. announce the appointment of **Mr. F. B. Strachan** as managing director of the company.

It is announced that **Mr. Bo Englund** has been appointed managing director of Atlas Copco de Portugal Ltda, Lisbon, **Mr. Harry Grevby** managing director of Atlas Copco Belgique, Brussels, **Mr. Stig Johansson** sales manager of Atlas Copco A.B., Stockholm, **Mr. Tore Adler** manager of the international advertising department, and **Mr. Carl-Henrik von Hartmansdorff,** formerly of the Swedish State Power Board, director of personnel of Atlas Copco A.B., Stockholm.

Mr. R. R. Parker has been appointed general sales manager, **Mr. S. C. Kennett** deputy general sales manager, and **Mr. D. M. Bruce** marketing manager of Tecalemit Limited.

Mr. D. G. Haigh, M.I.E.E., has been appointed export manager of Chloride Batteries Ltd.

The General Electric Co. Ltd. announce that they have appointed **Mr. S. W. Hyde** as works superintendent, **Mr. F. J. Beesley** as works manager, and **Mr. W. E. J. Rees** as production manager and assistant works manager at their Erith works.

Mr. W. F. Cartwright, D.L., J.P., assistant managing director of The Steel Company of Wales Limited, has been appointed a director of Davy and United Engineering Company Limited.

Mr. R. W. Stobbs, F.R.I.C., F.I.M., has been appointed general manager of Preformations Limited, of Cheney Manor, Swindon.

Mr. R. Craig Wood has been elected a director of Associated Electrical Industries Limited. He is managing director of A.E.I.-Hotpoint Ltd. and chairman of A.E.I.-Gala Ltd.

Owing to the retirement of their director, **Dr. J. G. Pearce, C.B.E.,** the Council of The British Cast Iron Research Association has appointed **Mr. H. Morrogh** as director, and **Dr. H. T. Angus** as deputy director. **Mr. T. E. Whiteside** will continue as secretary.

Mr. Fred Cousans, F.I.M., foundry superintendent and local director since 1947, **Mr. George Wood, A.MET., A.I.M.,** heat treatment superintendent and local director, and **Mr. R. C. Heys,** managing director of Millspaugh Ltd., have been appointed to the board of Hadfields Limited, of Sheffield.

John Shaw & Sons, Wolverhampton, Ltd., announce that **Mr. Gilbert Roughton,** technical sales director of Jenks Brothers Ltd. and the British Tool & Engineering Co. Ltd., has been appointed to the board of the parent company, John Shaw & Sons, Wolverhampton, Ltd. He has also joined the board of the Sheffield subsidiaries, Moore & Wright (Sheffield) Ltd., and The Avia Steel & Tool Co. Ltd. **Mr. D. A. Tandy,** secretary of the parent company, has been appointed to the board of that company and all its subsidiary companies. **Mr. A. M. Lloyd,** sales manager of Jenks Brothers Ltd. and The British Tool & Engineering Co. Ltd., has been appointed a director of these companies. **Mr. W. H. Elsmore,** works manager, and **Mr. C. H. B. Cox,** production manager, have been appointed directors of The British Tool & Engineering Co. Ltd. **Mr. W. Rushby,** sales manager of Moore & Wright (Sheffield) Ltd., has been appointed director of that company and of The Avia Steel & Tool Co. Ltd.

Associated British Engineering Ltd. announce that **Mr. David Bruce,** managing director of British Polar for 22 years, has been appointed deputy chairman of the parent company and has been succeeded as managing director by **Mr. J. M. Watson. Mr. R. H. Arnold,** former general manager of British Polar, has been appointed works director, and **Mr. O. R. Guard,** the group's deputy chairman, vice chairman. **Mr. Allen A. Scaife** will continue to take full responsibility for the company's sales and contract activities.

Mr. T. A. HAMMERSLEY

It is with deep regret that we announce the death, following a protracted illness, of Mr. T. A. Hammersley, on January 27, at the age of 64. Mr. Hammersley was joint managing director of Marco Conveyor and Engineering Co. Ltd., and had been with his company for over 30 years.

BUSINESS NOTES

E. P. Barrus (Concessionaires) Ltd. have opened a new branch for the sales and distribution of machinery and equipment in Manchester at Deansgate House, 274 Deansgate, Manchester 3.

A new firm, **R. F. Fraser-Smith,** of 69 Kings Cross Road, London, W.C.1., (Tel: TERminus 1064/5), has been set up for the manufacture and supply of industrial radiographic equipment and accessories.

W. H. Dorman & Co. Ltd., of Stafford, manufacturers of diesel engines, have completed negotiations for the acquisition of the share capital and undertaking of **W. G. Bagnall Ltd.,** of Stafford, manufacturers of diesel locomotives, from **The Heenan Group Ltd.,** of Worcester.

"RUBERT" High Precision Feeler Gauges

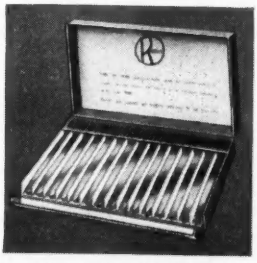
can be supplied

AS LOOSE BLADES IN PLASTIC CONTAINERS
IN BOXES OF ASSORTED BLADES to simplify storekeeping

Ideally suitable in the workshop, Inspection Room, etc. as Packings, Shim Steel, etc. From 0.0008" to 0.030"

Ask for leaflets

We also make any thickness and size of Feeler Gauges to customers requirements



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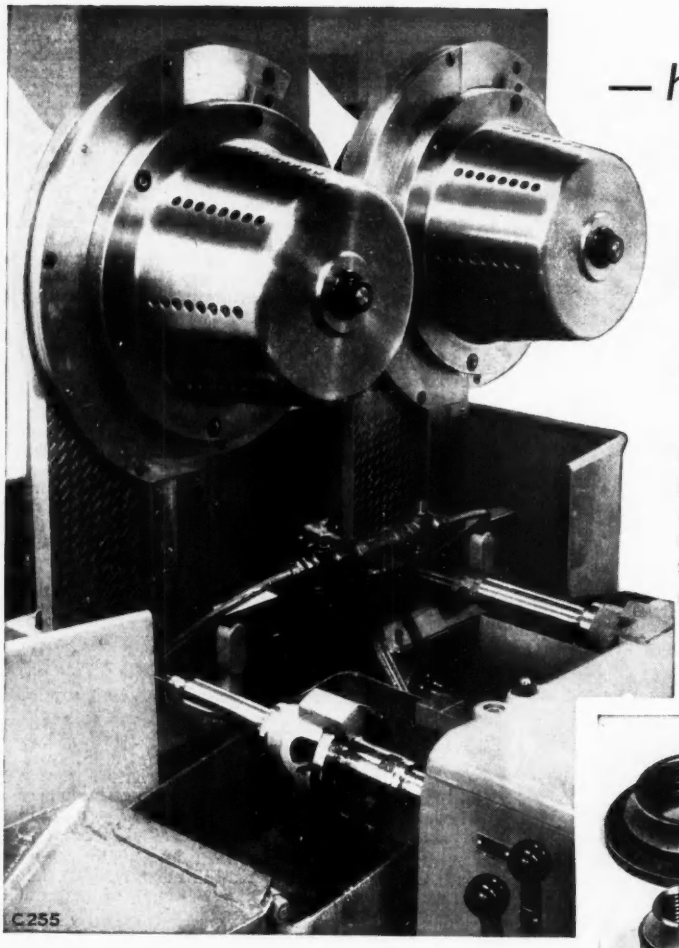


— high production nut tapping on KOSFELD automatics

Ingenious hopper feed prevents nuts jamming.

Automatic sorting and location of nuts ready for tapping is assured.

Simple to operate and economical in production; one operator can run several machines.

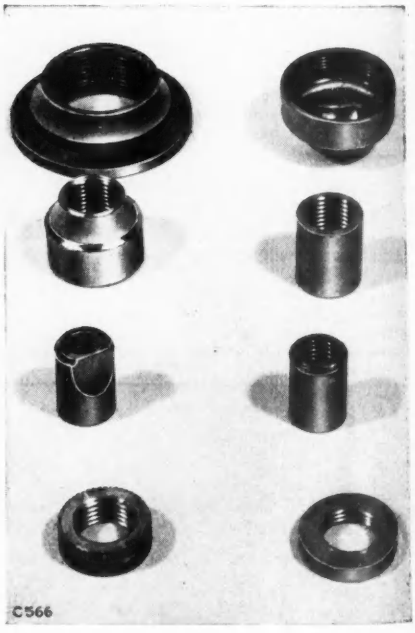
(Above) Shows a twin-spindle machine complete with rotary feed hoppers set-up for tapping $3\frac{3}{8}$" and $\frac{1}{2}$" Whit. nuts at the rate of 1,000 and 600 per hour respectively.

Made in five sizes, single or twin spindles, for threads from $\frac{1}{8}$ in. to 2 in. Whit.

Single-spindle machines can be fitted with a blind-hole tapping attachment.

Twin spindles operate independently; nuts of different sizes can be threaded simultaneously on the two spindles as illustrated above.

(Right) Apart from tapping blank, cold- or hot-pressed square, hexagon or round nuts many small components such as illustrated can be rapidly and automatically tapped.



AD.291

ALFRED HERBERT LTD., COVENTRY

Keelavite Hydraulics Limited have appointed **Elettro Tecnica Apparecchiature (ETA)** as their agents in Italy for the sale of hydraulic installations and units. The head office of ETA is at Piazza Guastalla 15, Milan, and their branches and agents cover the whole of Italy.

Pilkington Brothers Limited have started work on new research laboratories at Lathom Park, Ormskirk, Lancs. The laboratories, when completed, will house 500 employees, including 150 science graduates.

The Institute of Physics announces that it is arranging a conference on "Some Aspects of Magnetism" to take place in Sheffield, from September 22 to 24, 1959.

A new company, **Griffin & George (Research and Development) Ltd.,** has been formed by the **Griffin & George Group** for research and development in the field of scientific instruments and apparatus for laboratory use and process control.

The **K.G.S. Bearing Company Ltd.,** of Wolverhampton, has changed its name to **F·A.G. Bearing Company Ltd.** The company is the sales division for F·A.G. ball, cylindrical, taper, and spherical roller bearings, and has branches at Aberdeen, Belfast, Glasgow, Manchester, and North Shields.

As a result of an increase in the demand of Kanigen-plated components, **Albright & Wilson (Mfg.) Ltd.,** the sole U.K. licensees for this process, have installed two additional plating tanks at their plant at Oldbury, Birmingham.

Following the reorganization of the sales and administrative departments of **Furnival & Co. Ltd.,** it is announced that their sales departments have been transferred to offices of the parent company, **Rhodes, Brydon and Youatt Limited,** at Waterloo Engineering Works, Stockport (Tel: STOckport 5257/8/9 and 2625/6). Other departments, including the accounts department, are now situated at their Reddish Works (Tel: HEAton Moor 4228). In addition, two new divisions have been formed, one for the sale of printing and paper-cutting machinery and the other for the sale of the patent Andantex reduction pulleys.

The Lightfoot Refrigeration Co. Ltd., of Wembley, Middx., and the **Gesellschaft für Linde's Eismaschinen AG,** of Wiesbaden, Germany, announce that they have signed an agreement for mutual collaboration, whereby the full range of products and technical resources of each company in the field of domestic and industrial refrigeration and air conditioning will be made available to the other.

Smiths Aircraft Instruments Limited and **Kelvin & Hughes Limited,** together with **Sperry Gyroscope Company Limited (Brentford Division),** announce an arrangement for collaboration in certain major projects for aircraft control and instrumentation systems covering all aspects of such enterprises.

IBM World Trade Laboratories Corporation announce the formation of a British subsidiary company, **IBM World Trade Laboratories (Great Britain) Limited.** Mr. W. S. Elliott, M.A., M.I.E.E., F.Inst.P., has been appointed managing director of the laboratories, which are at present situated at Hursley House, near Winchester, Hampshire.

Varatio-Strateline Gears Ltd., of Slough, manufacturers of the Varatio variable-speed gearbox and the Strateline speed reducer, have appointed **Wm. Don Ltd.,** of Crown Point Bridge, Leeds 9 (Tel: Leeds 33781), as their representatives for Lancashire and Cheshire.

A private company, **Perkins Outboard Marine Ltd.,** has been formed by **F. Perkins Ltd.,** of Peterborough, to market the company's new petrol outboard motors.

The permanent-magnet business previously carried on by the **English Steel Rolling Mill Corporation Ltd.** has been transferred to the **English Steel Magnet Corporation Ltd.,** of Openshaw, Manchester, a subsidiary of the **English Steel Corporation Ltd.,** of Sheffield.

Steel & Co. Ltd., of Sunderland, have made an offer to buy the whole of the ordinary stock of **R. H. Neal & Co. Ltd.,** of Ealing and Grantham, manufacturers of the Neal mobile crane, and have also purchased the crane business of **F. Taylor & Sons (Manchester Ltd.** Steel & Co. Ltd. now control three of the largest British manufacturers of mobile and rail cranes.

Oxy-Catalyst Sales Ltd. announce that their technical sales department has moved to Rayleigh House, High Street, Great Bookham, Surrey (Tel: Bookham 3836/7), while their head office remains at Henley Park, Guildford, Surrey.

The 16th annual Radio and Electronic Component Show, organized by the **Radio and Electronic Component Manufacturers' Federation,** is to be held at Grosvenor House and Park Lane House, London, W.1, from April 6 to April 9, 1959.

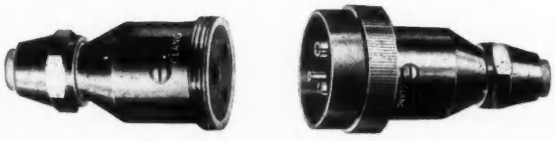
Simmonds Aerocessories Limited, a member of The Firth Cleveland Group, announce the formation of a subsidiary company in Germany under the name of **Deutsche Firth Cleveland GmbH.**

CONTRACTS

Wild-Barfield Electric Furnaces Ltd., of Watford, Herts, announce that they have received from the U.S.A. a second order, valued at about $300,000, for the supply of induction-heated aluminium-holding furnaces of 750 lb capacity.

British Oxygen Linde Limited has been awarded a contract for an oxygen plant, worth nearly £750,000, placed by Humphreys & Glasgow Limited, who are building Britain's first Lurgi pressure-gasification plant for the production of town gas at Westfield, Fifeshire.

WEATHERPROOF ACCESSORIES



A RANGE OF PLUGS AND SOCKETS FOR USE WHEREVER A MORE ROBUST AND STURDY TYPE OF ELECTRICAL CONNECTION IS NECESSARY.

ILLUSTRATED CATALOGUE ON REQUEST.

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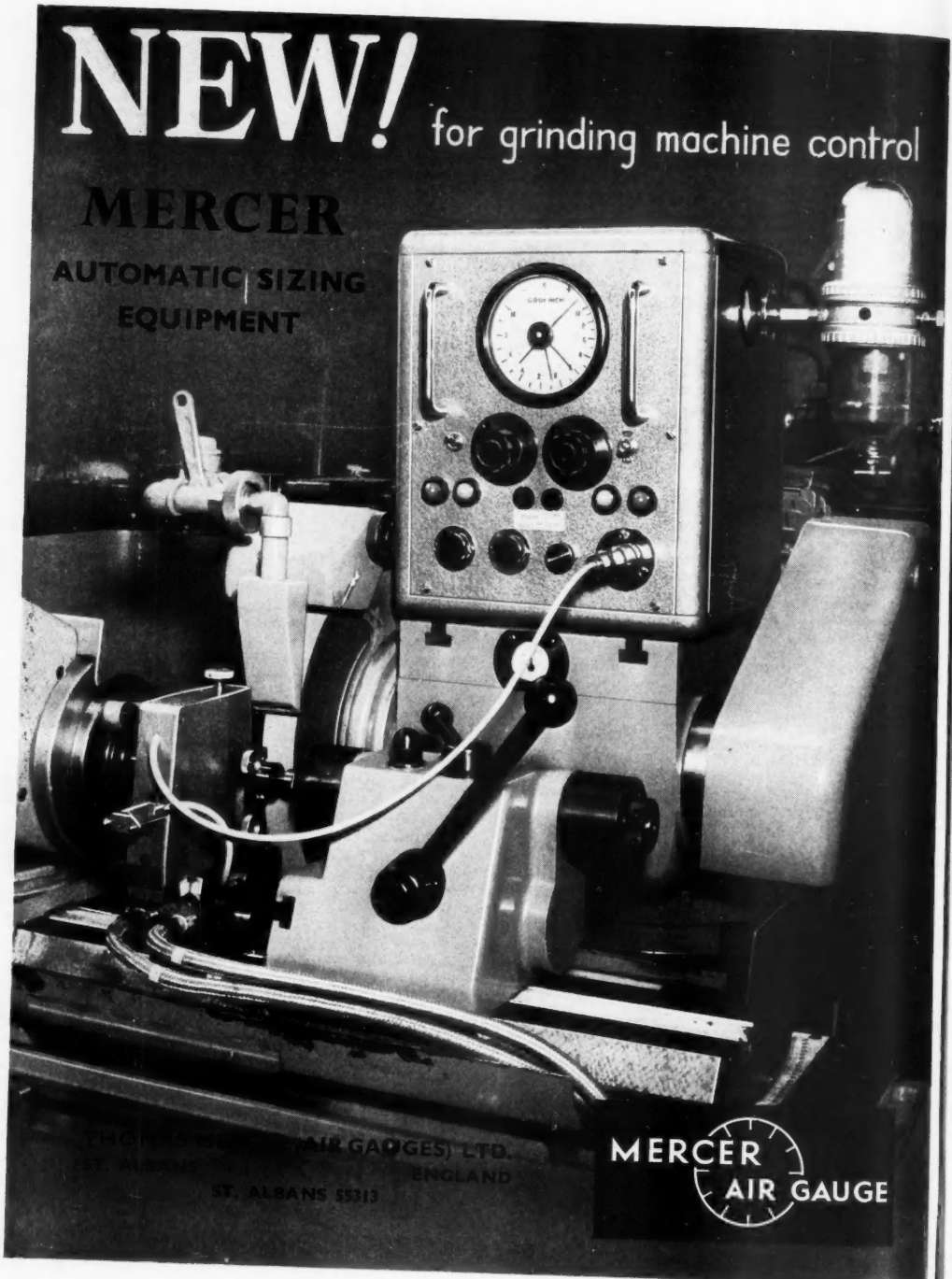
GLADSTONE 4201 (5 lines)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for grinding machine control
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AUTOMATIC SIZING
EQUIPMENT
ENGLAND
ST. ALBANS 55313
MERCER
AIR GAUGE

Davey, Paxman & Co. Ltd. have received from Cellulose Development Corporation an order to the value of over £50,000 for the supply of 5 large rotary vacuum filters, a digestion tower, and a soaking machine, as part of a £250,000 contract for equipping a paper-pulp mill in China.

A contract, valued at over £200,000, has been placed with The General Electric Co. Ltd. for the supply of two turbo-blowers for the new works of South Durham Iron and Steel Co. Ltd., of West Hartlepool.

Siemens Edison Swan (Export) Ltd. have obtained a contract worth £26,000 for P.V.C.-insulated cables from the Damodar Valley Corporation, of India.

The Hawker Siddeley Group announce that, in the face of keen Japanese and Italian competition, they have received an order worth over £2,250,000 from Argentina for the supply of six 10-MW Brush-Ljungström turbo-generators.

The Kestner Evaporator and Engineering Co. Ltd., of London, have concluded negotiations with the V/O Techmashimport, of Moscow, to supply a large spray-drying plant for sodium sulphate to be delivered to Russia this year.

A Russian order for more than £70,000 worth of plastics mixing machines has been placed with the Morton Machine Co. Ltd., of Wishaw, Scotland.

"MASTERS OF STEEL"

Eighty years have passed since Mr. Francis Henry Lloyd founded the James Bridge Steelworks at Wednesbury, South Staffs. Since then, this firm, now known as F. H. Lloyd & Co. Ltd., has developed into one of the major steelfounders of Britain, with an annual output of 20,000 tons of castings. A recently published illustrated booklet, entitled "Masters of Steel", gives an interesting account of the history of the company and of the new production processes employed. The manufacturing range of the plant includes castings for turbines, railways, earth-moving and metal-working machines, valve components, etc., and examples of these are included in this publication.

EXHIBITION OF STELVETITE

After two years of development, Stelvetite, the plastic-coated steel sheet, one side of which is electro-zinc coated and the other permanently covered with a specially formulated P.V.C., has reached its production stage and is already widely used in various fields of industry. An exhibition of Stelvetite, which is manufactured by John Summers & Sons Limited, was held in January at the Royal Festival Hall, and demonstrated its extensive processing characteristics which include good welding, soldering, seaming, deep-drawing, and cold-forming properties, together with some of its applications in architecture, machines, instruments, electrical and domestic equipment, vehicles, etc.

THE LEIPZIG SPRING FAIR

The Leipzig Spring Fair, to be held from March 1 to 10, will cover an exhibition area of over 3,000,000 sq ft, the majority of which will be devoted to technical goods, ranging from examples of heavy-engineering construction to precision equipment. Altogether, about 9000 exhibitors will take part from 40 countries, 23 countries being represented by collective shows.

11th BRITISH ELECTRICAL POWER CONVENTION

"Electricity and its Contribution to the Standard of Living" is the theme of the 11th British Electrical Power Convention, to be held in Torquay from June 1 to 5 under the presidency of Mr. C. R. King, C.B.E., Comp. I.E.E., M.Inst.F., deputy chairman of the Central Electricity Generating Board. As in former years, there will be an electrical exhibition associated with the convention. Papers to be presented include a discussion on the first nuclear power stations, papers on industrial, commercial, and domestic electrical progress, on electrical contracting, and on safety in the home.

INTERNATIONAL PLASTICS EXHIBITION

Fully international for the first time since its inception in 1951, the International Plastics Exhibition, to be held at Olympia from June 17 to 27, will put on show plastics materials and finished products from 15 countries. Britain's own plastics industry, third largest in the world, will be represented by more than 200 firms showing the latest achievements in the chemistry, mechanics, and merchandising of plastics.

CONFERENCE ON IRON AND STEEL WORKS BUILDINGS

Under the auspices of The British Iron & Steel Research Association, a conference was held from January 13 to 15 at Ashorne Hill, Warwickshire, on various constructional problems of iron and steel works. Papers presented included discussions on foundations and superstructures, maintenance, and design problems of buildings. Two papers, submitted respectively by German and French engineers, discuss the problems of erection of new works and of extending existing plant in their countries.

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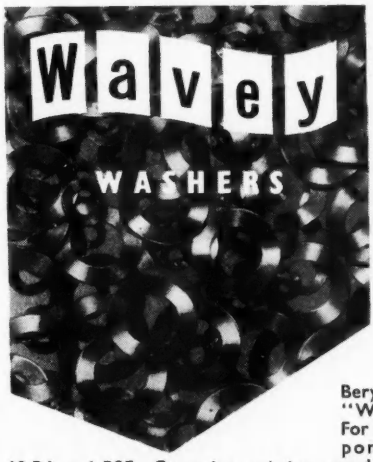

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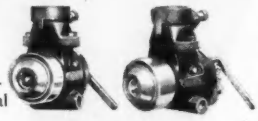

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NEW TECHNICAL BOOKS

Aircraft and Missile Propulsion (Vol. II: *The Gas-Turbine Power Plant, the Turbo-prop, Turbo-jet, Ramjet, and Rocket Engines*). By M. J. Zucrow. 650 pp., 260 illustrations. Publishers: John Wiley & Sons, Inc., New York, and Chapman & Hall, Ltd., 37 Essex Street, London, W.C.2. Price: 104/–.

This excellent book is the second in a three-volume series designed to furnish students and practising engineers with an understanding of the underlying principles of the technology of turbo-prop, turbo-jet, ram-jet, liquid-propellant rocket, and solid-propellant rocket engines. Whereas Vol. I in the series (reviewed in these columns in our issue of November 1958) was concerned with the thermodynamics of fluid flow and its applications to propulsion engines, Vol. II deals with the analysis of the cycles and performance characteristics of these engines.

As before, Professor Zucrow has made special efforts to present his subject matter clearly, and includes detailed explanations of all derivations, references at the end of each chapter, and a large number of illustrative problems worked out completely.

Metallic Rectifiers and Crystal Diodes. By Theodore Conti. 164 pp., 84 illustrations. Publishers: John F. Rider Publisher, Inc., 116 West 14th Street, New York 11, N.Y. Price $2.95.

Explaining simply but comprehensively the principles and uses of metallic rectifiers and crystal diodes in a wide range of applications, this well-written and illustrated book successfully achieves its aim of adding materially to the technical background and capabilities of engineers, students, and all those who are interested in modern ideas of electronic technology.

Essentially, the book is a compilation in one volume of the most useful basic information on these semiconductor units. After a brief summary of their historical background, descriptions are given of the manufacturing techniques employed in single-cell assembly and stacking methods, basic circuit-design data, and testing procedures for ascertaining the quality of new and used metallic rectifiers and crystal diodes. In addition, the basic theory and construction of these devices, and their varied applications and practical possibilities are discussed, while a comprehensive appendix contains such useful information as the standard for coding industrial dy-disc rectifiers, and a complete listing of silicon- and germanium-diode specification data.

Russian/English Technical Dictionaries.

With the increasing interest in Russian developments in practically all fields of engineering and science, it is hardly surprising that there is a steadily growing demand on the part of engineers, research workers, and editors of technical publications generally for up-to-date, reliable, and accurate Russian/English technical dictionaries. Three of these dictionaries, each very good in its own field, have recently been received and are reviewed below.

(1) *Russian/English Technical and Chemical Dictionary*. Fifth printing, 1958. By Ludmilla Ignatiev Callaham. 794 pages. Publishers: John Wiley & Sons, Inc., New York, and Chapman & Hall Ltd., 37 Essex Street, London, W.C.2. Price: 132/–.

This dictionary covers an extremely wide range of terms used in such industries as those concerned with plastics, rubber, petroleum, paper, food, agriculture, metallurgy, mining, chemistry, mechanical and electrical engineering, etc. In fact, since the work is mainly intended for English-speaking scientists with a fair knowledge of Russian, it includes a general vocabulary consisting of virtually all types of words which might appear in technical articles.

(2) *Russian/English/Russian Electronics Dictionary*. 943 pages. Published 1958 by the McGraw-Hill Book Company, New York, and the McGraw-Hill Publishing Company Ltd., 95 Farringdon Street, London, E.C.4. Price: 62/–.

Basically intended as an aid to translators, writers, engineers, and scientists who may have occasion to use Russian-language publications dealing with electronics and telecommunications, this comprehensive dictionary is an overall collection of about 22,000 Russian terms and abbreviations covering a wide range of fields, including antennas and wave-guides, aeronautical applications, batteries, beacons, cables, computers, electronics, radar, radio, telephony, television, electronic instruments, sound recording, and X-rays. Although a pioneer work in its field, it is undeniably up-to-date, as all modern sources available have been used in its compilation. In addition to sources in the U.S.A., Russia, and Great Britain, many Russian terms have been obtained directly from Soviet factories, research institutions, and individual scientists.

(3) *Russian/English Atomic Dictionary*. First Edition, 1957. By Dr. Eugene A. Carpovich. 317 pages. Publishers: Technical Dictionaries Co., P.O. Box 144, New York 31, N.Y. Price: $12.00.

Comprising more than 23,000 Russian entries, this excellent dictionary, though mainly concerned with nuclear science and technology, also covers many terms used in physics, mathematics, chemistry, metallurgy and metallography, and biophysics and radiobiology, as well as a number of general technical and scientific terms. This dictionary, although originally published two years ago, is still comprehensive and up-to-date, and despite the fact that a second edition is contemplated, it is anticipated that it will incorporate comparatively few modifications.

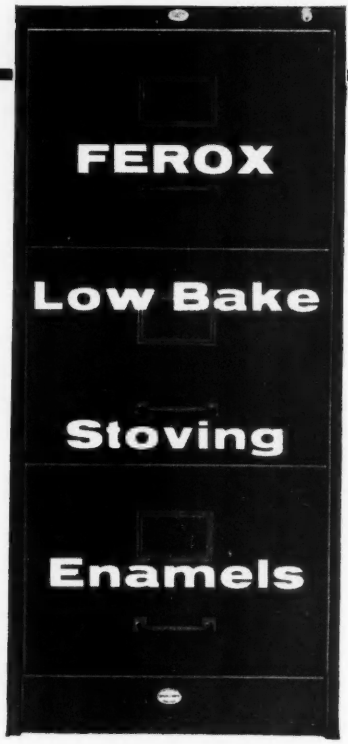
Kempe's Engineers Year-Book, 1959. 64th Edition. Edited by C. E. Prockter, M.I.E.E., M.I.Mech.E., under the direction of B. W. Pendred, M.I.Mech.E., M.I.S.I. 2760 pages. Publishers: Morgan Brothers (Publishers) Ltd., 28 Essex Street, London, W.C.2. Price: 82/6 (two volumes in case); postage 2/6.

As always, the 79 chapters in this well-known reference book cover practically every branch of engineering, and every year close attention is given to each chapter to ensure that it is completely up to date. This year is no exception; thus, the chapters on "Flow Metering and Mechanical Testing", "Refrigeration", and "Paints and Varnishes" have been completely rewritten, while additions have been made to no fewer than 24 other chapters, and all have been revised, where necessary. In short, this 64th edition, like its predecessors, is a comprehensive and authoritative work on a remarkably wide range of subjects.

Jig and Fixture Details and Units. By H. W. Hardy, A.M.I.Mech.E. 172 pp., 133 illustrations. Publishers: The Machinery Publishing Co. Ltd., National House, 21 West Street, Brighton 1. Price: 18/6.

Constituting a direct reference for jig designers, this latest addition to the well-known Standard Reference Series published by *Machinery* contains drawings of all the necessary parts of jigs and fixtures, with suggested designs for a range of units. Each drawing is accompanied by a table of detail dimensions to suit various applications.

It is assumed that jig and fixture draughtsmen already possess a good knowledge of the nomenclature, essential features, and details adopted in the design and construction of jigs and fixtures. With this assumption in mind, the tables in this book serve as a valuable guide to the practical design and proportioning of many of the details and units which are most used in jig and fixture construction.



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In addition, details are given of the company's activities in producing precision forged compressor blades and turbine blades for gas turbines and high-temperature steam turbines to exceptionally high standards of dimensional accuracy, surface finish, and control of metallurgical structure, and also short descriptions of the facilities of the company for producing hardened forged steel rolls for cold-rolling operations.

2. Sintered Metal Components. Details are contained in an illustrated 8-page booklet of the basic principles, of the method of producing sintered metal components for engineering purposes, together with illustrations of a number of representative examples, including roller-bearing cages, power-brake actuators, drive couplings, and parts for oil pumps, shock-absorbers, and anti-friction bearings.

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3. Cold-Rolled Steel Strip and Flattened Wire. A 10-page illustrated brochure contains details of a range of recently introduced cold-rolled steel strip and flattened wire for a wide variety of applications, ranging from machine knives to camera shutters. In addition to illustrating the range by means of coloured graphs, the brochure contains useful information on the properties and applications of various grades of strip, including clearly drawn graphic tables of hardness comparisons and equivalent tensile strengths.

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5. Positive-Displacement Rotary Compressors. Details are contained in a series of well-produced and illustrated 4-page brochures of a range of compact and efficient positive-displacement rotary compressors. These compressors are of mechanically simple design, consisting essentially of two rotors, a casing, four journal bearings, thrust bearings, and timing gears. In the smaller sizes, an integral speed-increasing gearbox is incorporated. Shaft seals and oil throwers are fitted to all compressors. The present range covers a volume between 650 and 23,000 cfm in single machines but, as they are inherently stable, two or more machines can be operated in parallel.

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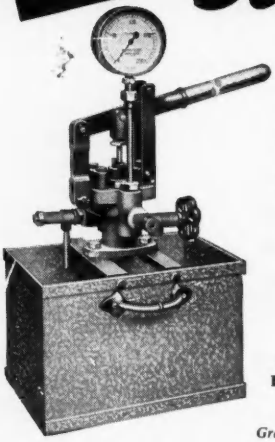

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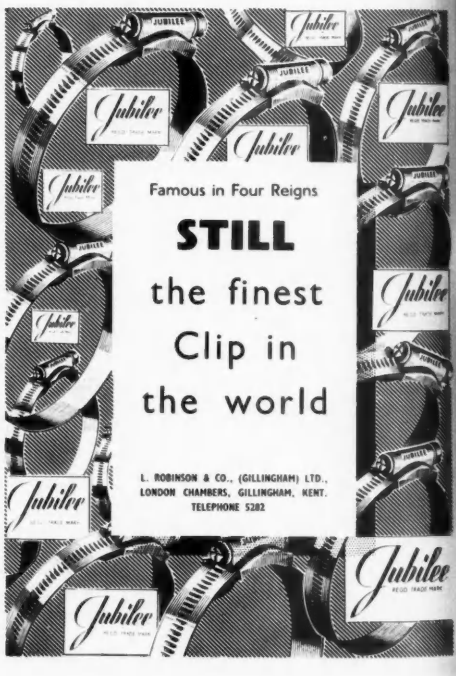
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